

B: Materials Reference

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Framing Calculation Approaches/Tables

When showing compliance with the building energy efficiency standard, the envelope assemblies U-value must meet the requirements of the standard. For wood and metal framed, light and heavy mass walls the tabulated default values or calculation methods presented in this section to determine the U-value of an assembly can be used in compliance.

U-VALUE CALCULATION PROCEDURE FOR CALCULATING METAL FRAMED ASSEMBLIES

B-4

This section includes sample calculations for metal framed assemblies and all of the ASHRAE methods, including the parallel path, zonal method, and isothermal plane method. To calculate the U-value of more complex assemblies or develop a better understanding of heat transfer through different types of construction assemblies users may reference this section.

FRAMED WALL ASSEMBLY U-VALUES

B-26-27

If the wall assembly is very generic or there is no need to take advantage or evaluate specific components of a construction assembly, the default U-values in Table B-2 can be used. Use of Table B-2 will significantly simplify compliance and save considerable time, however, the assumption used to develop these default tables are very conservative.

METAL FRAMING FACTORS

B-29

This table includes values reference in Chapter 3 to be used to adjust U-value calculations using a parallel method when metal framing is used.

PROPERTIES OF MASONRY WALLS

B-30-32

These tables list the U-value and Heat Capacity of basic types of masonry block construction. They also include the effects of insulation placed on block walls.

FRAMED WALL/FLOOR/CEILING ASSEMBLIES U-VALUES

B-33-82

This table refers to Table B7 that includes diagrams and assembly U-value calculation for some basic ceiling and floor assemblies.

COMPUTER MODELING OF FRAMED ASSEMBLIES

B-83

This Commission has developed the EZFRAME program to automate ASHRAE procedures in order to help the building community in calculating the U-values of wood and metal framed assemblies with a higher degree of accuracy and speed. The output forms of this program can be used as part of a residential or nonresidential submittal.

Table B-1

CHAPTER 22

THERMAL AND WATER VAPOR TRANSMISSION DATA

Building Envelopes 22.1
Calculating Overall Thermal Resistances 22.3
Mechanical and Industrial Systems 22.17
Calculating Heat Flow for Buried Pipelines 22.19

THIS chapter presents thermal and water vapor transmission data based on steady-state or equilibrium conditions. Chapter 3 covers heat transfer under transient or changing temperature conditions. Chapter 20 discusses selection of insulation materials and procedures for determining overall thermal resistances by simplified methods.

BUILDING ENVELOPES

Thermal Transmission Data for Building Components

The steady-state thermal resistances (R-values) of building components (walls, floors, windows, roof systems, etc.) can be calculated from the thermal properties of the materials in the component; or the heat flow through the assembled component can be measured directly with laboratory equipment such as the guarded hot box (ASTM *Standard* C 236) or the calibrated hot box (ASTM *Standard* C 976).

Tables 1 through 6 list thermal values, which may be used to calculate thermal resistances of building walls, floors, and ceilings. The values shown in these tables were developed under ideal conditions. In practice, overall thermal performance can be reduced significantly by such factors as improper installation and shrink-

age, settling, or compression of the insulation (Tye and Desjarlais 1983, Tye 1985, 1986).

Most values in these tables were obtained by accepted ASTM test methods described in ASTM *Standards* C 177 and C 518 for materials and ASTM *Standards* C 236 and C 976 for building envelope components. Because commercially available materials vary, not all values apply to specific products. (Previous editions of the handbook can be consulted for data on materials no longer commercially available.)

The most accurate method of determining the overall thermal resistance for a combination of building materials assembled as a building envelope component is to test a representative sample by a hot box method. However, all combinations may not be conveniently or economically tested in this manner. For many simple constructions, calculated R-values agree reasonably well with values determined by hot box measurement.

The performance of materials fabricated in the field is especially subject to the quality of workmanship during construction and installation. Good workmanship becomes increasingly important as the insulation requirement becomes greater. Therefore, some engineers include additional insulation or other safety factors based on experience in their design.

Figure 1 shows how convection affects surface conductance of several materials. Other tests on smooth surfaces show that the average value of the convection part of conductance decreases as the length of the surface increases.

Table 1 Surface Conductances and Resistances for Air

Position of Surface	Direction of Heat Flow	Surface Emittance, ϵ					
		Non-reflective		Reflective			
		$\epsilon = 0.90$	$\epsilon = 0.20$	$\epsilon = 0.05$			
		h_i	R	h_i	R	h_i	R
STILL AIR							
Horizontal	Upward	1.63	0.61	0.91	1.10	0.76	1.32
Sloping—45°	Upward	1.60	0.62	0.88	1.14	0.73	1.37
Vertical	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70
Sloping—45°	Downward	1.32	0.76	0.60	1.67	0.45	2.22
Horizontal	Downward	1.08	0.92	0.37	2.70	0.22	4.55
MOVING AIR (Any position)							
15-mph Wind (for winter)		h_o	R	h_o	R	h_o	R
7.5-mph Wind (for summer)		6.00	0.17	—	—	—	—
		4.00	0.25	—	—	—	—

Notes:

1. Surface conductance h_i and h_o measured in $\text{Btu}/\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$; resistance R in $^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h}/\text{Btu}$.
2. No surface has both an air space resistance value and a surface resistance value.
3. For ventilated attics or spaces above ceilings under summer conditions (heat flow down), see Table 5.
4. Conductances are for surfaces of the stated emittance facing virtual blackbody surroundings at the same temperature as the ambient air. Values are based on a surface-air temperature difference of 10°F and for surface temperatures of 70°F .
5. See Chapter 3 for more detailed information, especially Tables 5 and 6, and see Figure 1 for additional data.
6. Condensate can have a significant impact on surface emittance (see Table 3).

The preparation of this chapter is assigned to TC 4.4, Thermal Insulation and Moisture Retarders.

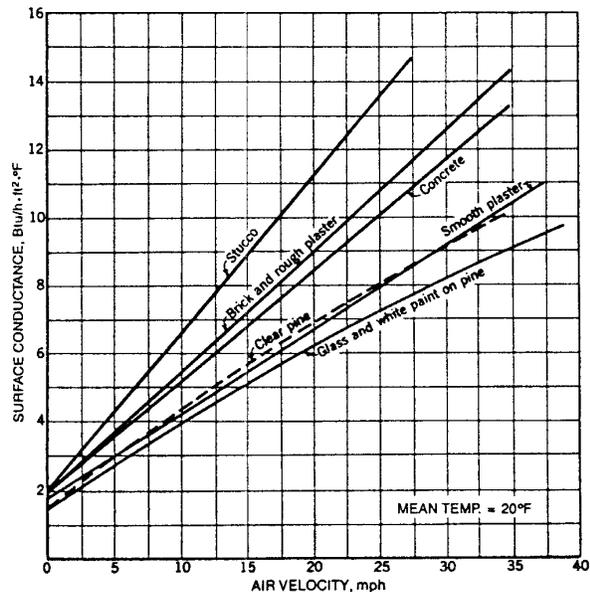


Fig. 1. Surface Conductance for Different 12-Inch-Square Surfaces as Affected by Air Movement

Table 2 Thermal Resistances of Plane Air Spaces^{a,b,c}, °F·ft²·h/Btu

Position of Air Space		Air Space		0.5-in. Air Space ^c					0.75-in. Air Space ^c				
		Direction of Heat Flow	Mean Temp. ^d , °F	Temp. Diff. ^d , °F	Effective Emittance $\epsilon_{eff}^{d,e}$					Effective Emittance $\epsilon_{eff}^{d,e}$			
				0.03	0.05	0.2	0.5	0.82	0.03	0.05	0.2	0.5	0.82
Horiz.	Up ↑	90	10	2.13	2.03	1.51	0.99	0.73	2.34	2.22	1.61	1.04	0.75
		50	30	1.62	1.57	1.29	0.96	0.75	1.71	1.66	1.35	0.99	0.77
		50	10	2.13	2.05	1.60	1.11	0.84	2.30	2.21	1.70	1.16	0.87
		0	20	1.73	1.70	1.45	1.12	0.91	1.83	1.79	1.52	1.16	0.93
		0	10	2.10	2.04	1.70	1.27	1.00	2.23	2.16	1.78	1.31	1.02
		-50	20	1.69	1.66	1.49	1.23	1.04	1.77	1.74	1.55	1.27	1.07
45° Slope	Up ↗	90	10	2.44	2.31	1.65	1.06	0.76	2.96	2.78	1.88	1.15	0.81
		50	30	2.06	1.98	1.56	1.10	0.83	1.99	1.92	1.52	1.08	0.82
		50	10	2.55	2.44	1.83	1.22	0.90	2.90	2.75	2.00	1.29	0.94
		0	20	2.20	2.14	1.76	1.30	1.02	2.13	2.07	1.72	1.28	1.00
		0	10	2.63	2.54	2.03	1.44	1.10	2.72	2.62	2.08	1.47	1.12
		-50	20	2.08	2.04	1.78	1.42	1.17	2.05	2.01	1.76	1.41	1.16
Vertical	Horiz. →	90	10	2.62	2.56	2.17	1.66	1.33	3.53	3.27	2.10	1.62	1.30
		50	30	2.47	2.34	1.67	1.06	0.77	3.50	3.24	2.08	1.22	0.84
		50	10	2.57	2.46	1.84	1.23	0.90	2.91	2.77	2.01	1.30	0.94
		0	20	2.66	2.54	1.88	1.24	0.91	3.70	3.46	2.35	1.43	1.01
		0	10	2.82	2.72	2.14	1.50	1.13	3.14	3.02	2.32	1.58	1.18
		-50	20	2.93	2.82	2.20	1.53	1.15	3.77	3.59	2.64	1.73	1.26
45° Slope	Down ↘	90	10	2.90	2.82	2.35	1.76	1.39	2.90	2.83	2.36	1.77	1.39
		50	30	3.20	3.10	2.54	1.87	1.46	3.72	3.60	2.87	2.04	1.56
		50	10	2.48	2.34	1.67	1.06	0.77	3.53	3.27	2.10	1.22	0.84
		0	20	2.64	2.52	1.87	1.24	0.91	3.43	3.23	2.24	1.39	0.99
		0	10	2.67	2.55	1.89	1.25	0.92	3.81	3.57	2.40	1.45	1.02
		-50	20	2.91	2.80	2.19	1.52	1.15	3.75	3.57	2.63	1.72	1.26
Horiz.	Down ↓	90	10	2.94	2.83	2.21	1.53	1.15	4.12	3.91	2.81	1.80	1.30
		50	30	3.16	3.07	2.52	1.86	1.45	3.78	3.65	2.90	2.05	1.57
		50	10	3.26	3.16	2.58	1.89	1.47	4.35	4.18	3.22	2.21	1.66
		0	20	2.48	2.34	1.67	1.06	0.77	3.55	3.29	2.10	1.22	0.85
		0	10	2.66	2.54	1.88	1.24	0.91	3.77	3.52	2.38	1.44	1.02
		-50	20	2.67	2.55	1.89	1.25	0.92	3.84	3.59	2.41	1.45	1.02

Position of Air Space		Air Space		1.5-in. Air Space ^c					3.5-in. Air Space ^c				
		Direction of Heat Flow	Mean Temp. ^d , °F	Temp. Diff. ^d , °F	Effective Emittance $\epsilon_{eff}^{d,e}$					Effective Emittance $\epsilon_{eff}^{d,e}$			
				0.03	0.05	0.2	0.5	0.82	0.03	0.05	0.2	0.5	0.82
Horiz.	Up ↑	90	10	2.55	2.41	1.71	1.08	0.77	2.84	2.66	1.83	1.13	0.80
		50	30	1.87	1.81	1.45	1.04	0.80	2.09	2.01	1.58	1.10	0.84
		50	10	2.50	2.40	1.81	1.21	0.89	2.80	2.66	1.95	1.28	0.93
		0	20	2.01	1.95	1.63	1.23	0.97	2.25	2.18	1.79	1.32	1.03
		0	10	2.43	2.35	1.90	1.38	1.06	2.71	2.62	2.07	1.47	1.12
		-50	20	1.94	1.91	1.68	1.36	1.13	2.19	2.14	1.86	1.47	1.20
45° Slope	Up ↗	90	10	2.37	2.31	1.99	1.55	1.26	2.65	2.58	2.18	1.67	1.33
		50	30	2.92	2.73	1.86	1.14	0.80	3.18	2.96	1.97	1.18	0.82
		50	10	2.14	2.06	1.61	1.12	0.84	2.26	2.17	1.67	1.15	0.86
		0	20	2.88	2.74	1.99	1.29	0.94	3.12	2.95	2.10	1.34	0.96
		0	10	2.30	2.23	1.82	1.34	1.04	2.42	2.35	1.90	1.38	1.06
		-50	20	2.79	2.69	2.12	1.49	1.13	2.98	2.87	2.23	1.54	1.16
Vertical	Horiz. →	90	10	2.22	2.17	1.88	1.49	1.21	2.34	2.29	1.97	1.54	1.25
		50	30	2.71	2.64	2.23	1.69	1.35	2.87	2.79	2.33	1.75	1.39
		50	10	3.99	3.66	2.25	1.27	0.87	3.69	3.40	2.15	1.24	0.85
		0	20	2.58	2.46	1.84	1.23	0.90	2.67	2.55	1.89	1.25	0.91
		0	10	3.79	3.55	2.39	1.45	1.02	3.63	3.40	2.32	1.42	1.01
		-50	20	2.76	2.66	2.10	1.48	1.12	2.88	2.78	2.17	1.51	1.14
45° Slope	Down ↘	90	10	3.51	3.35	2.51	1.67	1.23	3.49	3.33	2.50	1.67	1.23
		50	30	2.64	2.58	2.18	1.66	1.33	2.82	2.75	2.30	1.73	1.37
		50	10	3.31	3.21	2.62	1.91	1.48	3.40	3.30	2.67	1.94	1.50
		0	20	5.07	4.55	2.56	1.36	0.91	4.81	4.33	2.49	1.34	0.90
		0	10	3.58	3.36	2.31	1.42	1.00	3.51	3.30	2.28	1.40	1.00
		-50	20	5.10	4.66	2.85	1.60	1.09	4.74	4.36	2.73	1.57	1.08
Horiz.	Down ↓	90	10	3.85	3.66	2.68	1.74	1.27	3.81	3.63	2.66	1.74	1.27
		50	30	4.92	4.62	3.16	1.94	1.37	4.59	4.32	3.02	1.88	1.34
		50	10	3.62	3.50	2.80	2.01	1.54	3.77	3.64	2.90	2.05	1.57
		0	20	4.67	4.47	3.40	2.29	1.70	4.50	4.32	3.31	2.25	1.68
		0	10	6.09	5.35	2.79	1.43	0.94	10.07	8.19	3.41	1.57	1.00
		-50	20	6.27	5.63	3.18	1.70	1.14	9.60	8.17	3.86	1.88	1.22

^aSee Chapter 20 section Factors Affecting Heat Transfer across Air Spaces. Thermal resistance values were determined from the relation, $R = 1/C$, where $C = h_c + \epsilon_{eff} h_r$, h_c is the conduction-convection coefficient, $\epsilon_{eff} h_r$ is the radiation coefficient $\approx 0.00686 \epsilon_{eff} [(t_m + 460)/100]^4$, and t_m is the mean temperature of the air space. Values for h_c were determined from data developed by Robinson *et al.* (1954). Equations (5) through (7) in Yarbrough (1983) show the data in Table 2 in analytic form. For extrapolation from Table 2 to air spaces less than 0.5 in. (as in insulating window glass), assume $h_c = 0.159(1 + 0.0016 t_m)/l$ where l is the air space thickness in inches, and h_c is heat transfer through the air space only.

^bValues are based on data presented by Robinson *et al.* (1954). (Also see Chapter 3, Tables 3 and 4, and Chapter 39). Values apply for ideal conditions, *i.e.*, air spaces of uniform thickness bounded by plane, smooth, parallel surfaces with no air leakage to or from the space. When accurate values are required, use overall U-factors determined through calibrated

hot box (ASTM C 976) or guarded hot box (ASTM C 236) testing. Thermal resistance values for multiple air spaces must be based on careful estimates of mean temperature differences for each air space.

^cA single resistance value cannot account for multiple air spaces; each air space requires a separate resistance calculation that applies only for the established boundary conditions. Resistances of horizontal spaces with heat flow downward are substantially independent of temperature difference.

^dInterpolation is permissible for other values of mean temperature, temperature difference, and effective emittance ϵ_{eff} . Interpolation and moderate extrapolation for air spaces greater than 3.5 in. are also permissible.

^eEffective emittance ϵ_{eff} of the air space is given by $1/\epsilon_{eff} = 1/\epsilon_1 + 1/\epsilon_2 - 1$, where ϵ_1 and ϵ_2 are the emittances of the surfaces of the air space (see Table 3).

Vapor retarders, outlined in Chapters 20 and 21, require special attention. Moisture from condensation or other sources may reduce the thermal resistance of insulation, but the effect of moisture must be determined for each material. For example, some materials with large air spaces are not affected significantly if the moisture content is less than 10% by weight, while the effect of moisture on other materials is approximately linear.

Ideal conditions of components and installations are assumed in calculating overall R-values (*i.e.*, insulating materials are of uniform nominal thickness and thermal resistance, air spaces are of uniform thickness and surface temperature, moisture effects are not involved, and installation details are in accordance with design). The National Bureau of Standards' Building Materials and Structures Report BMS 151 shows that measured values differ from calculated values for certain insulated constructions. For this reason, some engineers decrease the calculated R-values a moderate amount to account for departures of constructions from requirements and practices.

Tables 2 and 3 give values for well-sealed systems constructed with care. Field applications can differ substantially from laboratory test conditions. Air gaps in these insulation systems can seriously degrade thermal performance as a result of air movement due to both natural and forced convection. Sabine *et al.* (1975) found that the tabular values are not necessarily additive for multiple-layer, low-emittance air spaces, and tests on actual constructions should be conducted to accurately determine thermal resistance values.

Values for foil insulation products supplied by manufacturers must also be used with caution because they apply only to systems that are identical to the configuration in which the product was tested. In addition, surface oxidation, dust accumulation, condensation, and other factors that change the condition of the low-emittance surface can reduce the thermal effectiveness of these insulation systems (Moroz 1951, Hooper and Moroz 1952). Deterioration results from contact with several types of solutions, either acidic or basic (*e.g.*, wet cement mortar or the preservatives found in decay-resistant lumber). Polluted environments may cause rapid and severe material degradation. However, site inspections show a predominance of well-preserved installations and only a small number of cases in which rapid and severe deterioration has occurred. An extensive review of the reflective building insulation system performance literature is provided by Goss and Miller (1989).

Table 3 Emittance Values of Various Surfaces and Effective Emittances of Air Spaces^a

Surface	Effective Emittance ϵ_{eff} of Air Space		
	Average Emittance ϵ	One Surface Emittance ϵ ; Other, 0.9	Both Surfaces Emittance ϵ
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (> 0.7gr/ft ²)	0.30 ^b	0.29	—
Aluminum foil, with condensate clearly visible (> 2.9 gr/ft ²)	0.70 ^b	0.65	—
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galvanized, bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

^aThese values apply in the 4 to 40 μm range of the electromagnetic spectrum.

^bValues are based on data presented by Bassett and Trethowen (1984).

CALCULATING OVERALL THERMAL RESISTANCES

Relatively small conductive elements within an insulating layer or thermal bridges can substantially reduce the average thermal resistance of a component. Examples include wood and metal studs in frame walls, concrete webs in concrete masonry walls, and metal ties or other elements in insulated wall panels. The following examples illustrate how to calculate R-values and U-factors for components containing thermal bridges.

The following conditions are assumed in calculating the design R-values:

- Equilibrium or steady-state heat transfer, disregarding effects of heat storage
- Surrounding surfaces at ambient air temperature
- Exterior wind velocity of 15 mph for winter (surface with $R = 0.17^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h}/\text{Btu}$) and 7.5 mph for summer (surface with $R = 0.25^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h}/\text{Btu}$)
- Surface emittance of ordinary building materials is 0.90

Wood Frame Walls

The average overall R-values and U-factors of wood frame walls can be calculated by assuming either parallel heat flow paths through areas with different thermal resistances or isothermal planes. Equations (1) through (5) from Chapter 20 are used.

For stud walls 16 in. on center (OC), the fraction of insulated cavity is about 0.75; the fraction of studs, plates, and sills is 0.21; and the fraction of headers is 0.04. For studs 24 in. OC, the respective values are 0.78, 0.18, and 0.04. These fractions contain an allowance for multiple studs, plates, sills, extra framing around windows, headers, and band joists.

Example 1A. Calculate the U-factor of the 2 by 4 stud wall shown in Figure 2. The studs are at 16 in. OC. There is 3.5-in. mineral fiber batt insulation (R-13) in the stud space. The inside finish is 0.5-in. gypsum wallboard; the outside is finished with rigid foam insulating sheathing (R-4) and 0.5-in. by 8-in. wood bevel lapped siding. The insulated cavity occupies approxi-

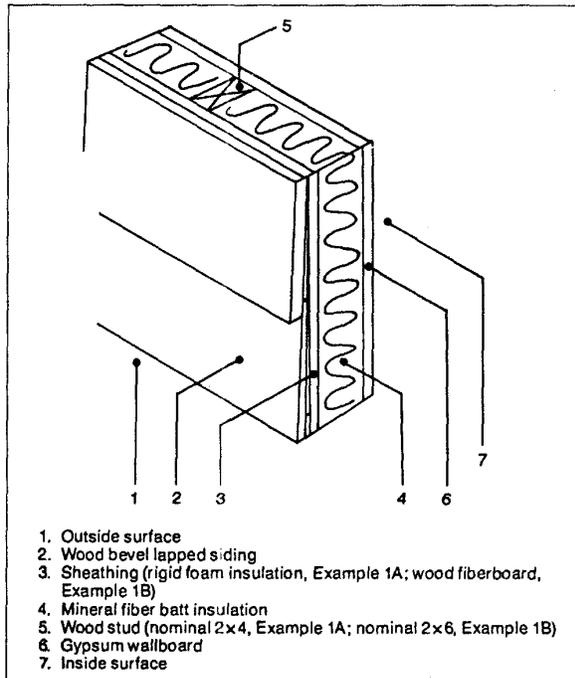


Fig. 2 Insulated Wood Frame Wall (Examples 1A and B)

mately 75% of the transmission area; the studs, plates, and sills occupy 21%; and the headers occupy 4%.

Solution: Obtain the R-values of the various building elements from Tables 1 and 4. Assume the R-value of the wood framing is R-1.25 per inch. Also, assume the headers are solid wood, in this case, and group them with the studs, plates, and sills.

Element	R (Insulated Cavity)	R (Studs, Plates, and Headers)
1. Outside surface, 15 mph wind	0.17	0.17
2. Wood bevel lapped siding	0.81	0.81
3. Rigid foam insulating sheathing	4.0	4.0
4. Mineral fiber batt insulation, 3.5 in.	13.0	—
5. Wood stud, nominal 2 × 4	—	4.38
6. Gypsum wallboard, 0.5 in.	0.45	0.45
7. Inside surface, still air	0.68	0.68
	$R_1 = 19.11$	$R_2 = 10.49$

Since the U-factor is the reciprocal of R-value, $U_1 = 0.052$ and $U_2 = 0.095 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$.

If the wood framing (thermal bridging) is not included, Equation (3) from Chapter 20 may be used to calculate the U-factor of the wall as follows:

$$U_{av} = U_1 = 1/R_1 = 0.052 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

If the wood framing is accounted for using the parallel flow method, the U-factor of the wall is determined using Equation (5) from Chapter 20 as follows:

$$U_{av} = (0.75 \times 0.052) + (0.25 \times 0.095) = 0.063 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

If the wood framing is included using the isothermal planes method, the U-factor of the wall is determined using Equations (2) and (3) from Chapter 20 as follows:

$$R_{T(av)} = 4.98 + 1/[(0.75/13.0) + (0.25/4.38)] + 1.13$$

$$= 14.82 \text{ }^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$

$$U_{av} = 0.067 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

For a frame wall with a 24-in. OC stud space, the average overall R-value becomes $15.18 \text{ }^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$. Similar calculation procedures can be used to evaluate other wall designs.

Example 1B. Calculate the U-factor of a 2 by 6 stud wall, similar to the one considered in Example 1A, except that the sheathing is 0.5-in. wood fiberboard and the studs are at 24 in. OC. There is 5.5-in. mineral fiber batt insulation (R-21) in the stud space. Assume the headers are double 2 by 8 framing (with a 0.5-in. air space), with a 2.0-in. air space between the headers and the wallboard.

Solution: Obtain the R-values of the various building elements from Tables 1 and 4. Assume the R-value of the wood framing is 1.25 per inch. In this case, the headers must be treated separately.

Element	R (Insulated Cavity)	R (Studs and Plates)	R (Headers)
1. Outside surface, 15 mph wind	0.17	0.17	0.17
2. Wood bevel lapped siding	0.81	0.81	0.81
3. Wood fiberboard sheathing, 0.5 in.	1.32	1.32	1.32
4. Mineral fiber batt insulation, 5.5 in.	21.0	—	—
5. Wood stud, nominal 2 × 6	—	6.88	—
6. Wood headers, double 2 × 8	—	—	3.75
7. Air space, 0.5 in.	—	—	0.90
8. Air space, 2 in.	—	—	0.90
9. Gypsum wallboard, 0.5 in.	0.45	0.45	0.45
10. Inside surface, still air	0.68	0.68	0.68
	$R_1 = 24.43$	$R_2 = 10.31$	$R_3 = 8.98$

Since U-factor is the reciprocal of R-value, $U_1 = 0.041$, $U_2 = 0.097$, and $U_3 = 0.111 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$.

If the wood framing is accounted for using the parallel flow method, the U-factor of the wall is determined using Equation (5) from Chapter 20 as follows:

$$U_{av} = (0.78 \times 0.041) + (0.18 \times 0.097) + (0.04 \times 0.111)$$

$$= 0.054 \text{ Btu} \cdot \text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

If the wood framing is included using the isothermal planes method, the U-factor of the wall is determined using Equations (2) and (3) from Chapter 20 as follows:

$$R_{T(av)} = 2.30 + 1/[(0.78/21.0) + (0.18/6.88) + (0.04/5.55)] + 1.13$$

$$= 17.61 \text{ }^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$

$$U_{av} = 0.057 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

If the headers are insulated with R-10 insulation, the average overall R-value becomes $18.57 \text{ }^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$.

For a frame wall with a 16-in. OC stud space and uninsulated headers, the average overall R-value becomes $17.05 \text{ }^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$. If the headers are insulated with R-10 insulation, the average overall R-value becomes $17.93 \text{ }^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$. Similar calculation procedures can be used to evaluate other wall designs.

Masonry Walls

The average overall R-values of masonry walls can be estimated by assuming a combination of layers in series, one or more of which provides parallel paths. This method is used because heat flows laterally through block face shells so that transverse isothermal planes result. Average total resistance $R_{T(av)}$ is the sum of the resistances of the layers between such planes, each layer calculated as shown in Example 2.

Example 2. Calculate the overall thermal resistance and average U-factor of the 7-5/8-in. thick insulated concrete block wall shown in Figure 3. The two-core block has an average web thickness of 1-in. and a face shell thickness of 1-1/4-in. Overall block dimensions are 7-5/8 by 7-5/8 by 15-5/8 in. Measured thermal resistances of 112 lb/ft³ concrete and 7 lb/ft³ expanded perlite insulation are 0.10 and $2.90 \text{ }^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$ per inch, respectively.

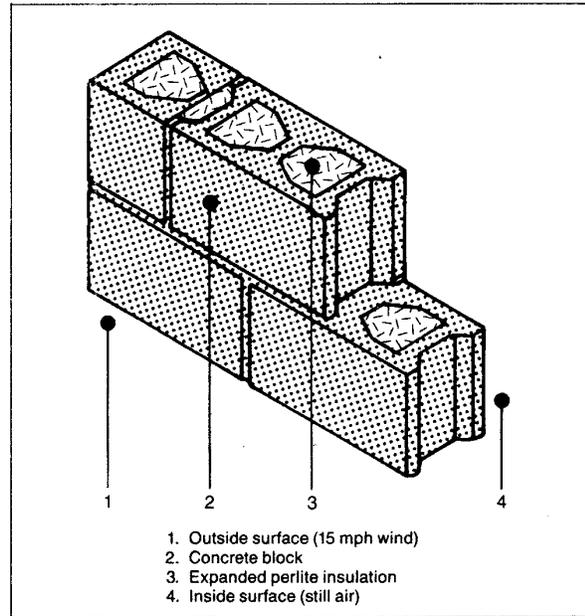


Fig. 3 Insulated Concrete Block Wall (Example 2)

Solution: The equation used to determine the overall thermal resistance of the insulated concrete block wall is derived from Equations (2) and (5) from Chapter 20 and is given below:

$$R_{T(av)} = R_i + R_f + \left(\frac{a_w}{R_w} + \frac{a_c}{R_c} \right)^{-1} + R_o$$

where

- $R_{T(av)}$ = overall thermal resistance based on assumption of isothermal planes
- R_i = thermal resistance of inside air surface film (still air)
- R_o = thermal resistance of outside air surface film (15 mph wind)
- R_f = total thermal resistance of face shells
- R_c = thermal resistance of cores between face shells
- R_w = thermal resistance of webs between face shells
- a_w = fraction of total area transverse to heat flow represented by webs of blocks
- a_c = fraction of total area transverse to heat flow represented by cores of blocks

From the information given and the data in Table 1, determine the values needed to compute the overall thermal resistance.

- $R_i = 0.68$
- $R_o = 0.17$
- $R_f = (2)(1.25)(0.10) = 0.25$
- $R_c = (5.125)(2.90) = 14.86$
- $R_w = (5.125)(0.10) = 0.51$
- $a_w = 3/15.625 = 0.192$
- $a_c = 12.625/15.625 = 0.808$

Using the equation given, the overall thermal resistance and average U-factor are calculated as follows:

$$R_{T(av)} = 0.68 + 0.25 + (0.51)(14.86)/[(0.808)(0.51) + (0.192)(14.86)] + 0.17$$

$$= 0.68 + 0.25 + 2.33 + 0.17 = 3.43 \text{ } ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$

$$U_{av} = 1/3.43 = 0.29 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

Based on guarded hot box tests of this wall without mortar joints, Tye and Spinney (1980) measured the average R-value for this insulated concrete block wall as $3.13 \text{ } ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$.

Assuming parallel heat flow only, the calculated resistance is usually higher than that calculated on the assumption of isothermal planes. The actual resistance generally is some value between the two calculated values. In the absence of test values, examination of the construction usually reveals whether a value closer to the higher or lower calculated R-value should be used. Generally, if the construction contains a layer in which lateral conduction is high compared with transmittance through the construction, the calculation with isothermal planes should be used. If the construction has no layer of high lateral conductance, the parallel heat flow calculation should be used.

Hot box tests of insulated and uninsulated masonry walls constructed with block of conventional configuration show that thermal resistances calculated using the isothermal planes heat flow method agree well with measured values (Van Geem 1985, Valore 1980, Shu *et al.* 1979). Neglecting horizontal mortar joints in conventional block can result in thermal transmittance values up to 16% lower than actual, depending on the density and thermal properties of the masonry, and 1 to 6% lower, depending on the core insulation material (Van Geem 1985, McIntyre 1984). For aerated concrete block walls, other solid masonry, and multicore block walls with full mortar joints, neglecting mortar joints can cause errors in R-values up to 40% (Valore 1988). Horizontal mortar joints usually found in concrete block wall construction are neglected in Example 2.

Panels Containing Metal

Curtain wall constructions often include metallic and other thermal bridges. The thermal resistance of panels can be signifi-

cantly reduced by metallic thermal bridges. However, the capacity of the adjacent facing materials to transmit heat transversely to the metal is limited, and some contact resistance between all materials in contact limits the reduction. Contact resistances in building structures are only 0.06 to $0.6 \text{ } ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$ —too small to be of concern in many cases. However, the contact resistances of steel framing members are important. Also, in many cases (as illustrated in Example 3), the area of metal in contact with the facing greatly exceeds the thickness of the metal which mitigates the influence.

Thermal characteristics for panels of sandwich construction can be computed by combining the thermal resistances of the various layers. However, few panels are true sandwich constructions; many have ribs and stiffeners that create complicated heat flow paths. R-values for the assembled sections should be determined on a representative sample by using a hot box method. If the sample is a wall section with air cavities on both sides of fibrous insulation, the sample must be of representative height since convective airflow can contribute significantly to heat flow through the test section. Computer modeling can also be useful, but all heat transfer mechanisms must be considered.

In Example 3, the metal member is only 0.020 in. thick, but it is in contact with adjacent facings over a 1.25 -in.-wide area. The steel member is 3.50 in. deep, has a thermal resistance of approximately $0.011 \text{ } ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$, and is virtually isothermal. The calculation involves careful selection of the appropriate thickness for the steel member. If the member is assumed to be 0.020 in. thick, the fact that the flange transmits heat to the adjacent facing is ignored, and the heat flow through the steel is underestimated. If the member is assumed to be 1.25 in. thick, the heat flow through the steel is overestimated. In Example 3, the steel member behaves in much the same way as a rectangular member 1.25 in. thick and 3.50 in. deep with a thermal resistance of $0.69 \text{ } ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$ [$(1.25/0.020) \times 0.011$] does. The Building Research Association of New Zealand (BRANZ) commonly uses this approximation.

Example 3. Calculate the C-factor of the insulated steel frame wall shown in Figure 4. Assume that the steel member has an R-value of $0.69 \text{ } ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$ and that the framing behaves as though it occupies approximately 8% of the transmission area.

Solution: Obtain the R-values of the various building elements from Table 4.

Element	R (Insul.)	R (Framing)
1. 0.5-in. gypsum wallboard	0.45	0.45
2. 3.5-in. mineral fiber batt insulation	11	—
3. Steel framing member	—	0.69
4. 0.5-in. gypsum wallboard	0.45	0.45
	$R_1 = 11.90$	$R_2 = 1.59$

Therefore, $C_1 = 0.084$; $C_2 = 0.629 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$.

If the steel framing (thermal bridging) is not considered, the C-factor of the wall is calculated using Equation (3) from Chapter 20 as follows:

$$C_{av} = C_1 = 1/R_1 = 0.084 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

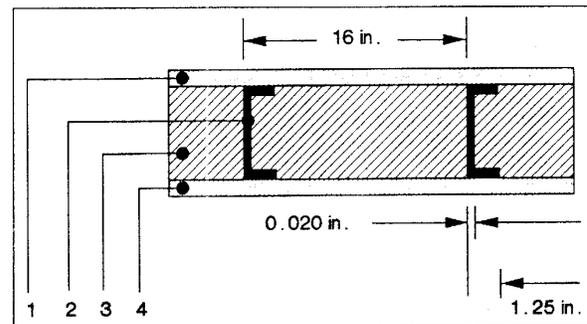


Fig. 4 Insulated Steel Frame Wall (Example 3)

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values^a

Description	Density, lb/ft ³	Conductivity ^b		Resistance ^c (R)		Specific Heat, Btu lb·°F
		(k), Btu·in h·ft ² ·°F	(C), Btu h·ft ² ·°F	Per Inch Thickness (1/k), °F·ft ² ·h Btu·in	For Thickness Listed (1/C), °F·ft ² ·h Btu	
BUILDING BOARD						
Asbestos-cement board	120	4.0	—	0.25	—	0.24
Asbestos-cement board 0.125 in.	120	—	33.00	—	0.03	—
Asbestos-cement board 0.25 in.	120	—	16.50	—	0.06	—
Gypsum or plaster board 0.375 in.	50	—	3.10	—	0.32	0.26
Gypsum or plaster board 0.5 in.	50	—	2.22	—	0.45	—
Gypsum or plaster board 0.625 in.	50	—	1.78	—	0.56	—
Plywood (Douglas Fir) ^d	34	0.80	—	1.25	—	0.29
Plywood (Douglas Fir) 0.25 in.	34	—	3.20	—	0.31	—
Plywood (Douglas Fir) 0.375 in.	34	—	2.13	—	0.47	—
Plywood (Douglas Fir) 0.5 in.	34	—	1.60	—	0.62	—
Plywood (Douglas Fir) 0.625 in.	34	—	1.29	—	0.77	—
Plywood or wood panels 0.75 in.	34	—	1.07	—	0.93	0.29
Vegetable fiber board						
Sheathing, regular density ^e 0.5 in.	18	—	0.76	—	1.32	0.31
Sheathing, regular density ^e 0.78125 in.	18	—	0.49	—	2.06	—
Sheathing intermediate density ^e 0.5 in.	22	—	0.92	—	1.09	0.31
Nail-base sheathing ^e 0.5 in.	25	—	0.94	—	1.06	0.31
Shingle backer 0.375 in.	18	—	1.06	—	0.94	0.31
Shingle backer 0.3125 in.	18	—	1.28	—	0.78	—
Sound deadening board 0.5 in.	15	—	0.74	—	1.35	0.30
Tile and lay-in panels, plain or acoustic 0.5 in.	18	0.40	—	2.50	—	0.14
Tile and lay-in panels, plain or acoustic 0.75 in.	18	—	0.80	—	1.25	—
Tile and lay-in panels, plain or acoustic 0.75 in.	18	—	0.53	—	1.89	—
Laminated paperboard	30	0.50	—	2.00	—	0.33
Homogeneous board from repulped paper	30	0.50	—	2.00	—	0.28
Hardboard^d						
Medium density	50	0.73	—	1.37	—	0.31
High density, service-tempered grade and service grade	55	0.82	—	1.22	—	0.32
High density, standard-tempered grade	63	1.00	—	1.00	—	0.32
Particleboard^e						
Low density	37	0.71	—	1.41	—	0.31
Medium density	50	0.94	—	1.06	—	0.31
High density	62.5	1.18	—	0.85	—	0.31
Underlayment 0.625 in.	40	—	1.22	—	0.82	0.29
Waferboard	37	0.63	—	1.59	—	—
Wood subfloor 0.75 in.	—	—	1.06	—	0.94	0.33
BUILDING MEMBRANE						
Vapor—permeable felt	—	—	16.70	—	0.06	—
Vapor—seal, 2 layers of mopped 15-lb felt	—	—	8.35	—	0.12	—
Vapor—seal, plastic film	—	—	—	—	Negl.	—
FINISH FLOORING MATERIALS						
Carpet and fibrous pad	—	—	0.48	—	2.08	0.34
Carpet and rubber pad	—	—	0.81	—	1.23	0.33
Cork tile 0.125 in.	—	—	3.60	—	0.28	0.48
Terrazzo 1 in.	—	—	12.50	—	0.08	0.19
Tile—asphalt, linoleum, vinyl, rubber	—	—	20.00	—	0.05	0.30
vinyl asbestos	—	—	—	—	—	0.24
ceramic	—	—	—	—	—	0.19
Wood, hardwood finish 0.75 in.	—	—	1.47	—	0.68	—
INSULATING MATERIALS						
<i>Blanket and Batt^{f,g}</i>						
Mineral fiber, fibrous form processed from rock, slag, or glass						
approx. 3–4 in.	0.4–2.0	—	0.091	—	11	—
approx. 3.5 in.	0.4–2.0	—	0.077	—	13	—
approx. 3.5 in.	1.2–1.6	—	0.067	—	15	—
approx. 5.5–6.5 in.	0.4–2.0	—	0.053	—	19	—
approx. 5.5 in.	0.6–1.0	—	0.048	—	21	—
approx. 6–7.5 in.	0.4–2.0	—	0.045	—	22	—
approx. 8.25–10 in.	0.4–2.0	—	0.033	—	30	—
approx. 10–13 in.	0.4–2.0	—	0.026	—	38	—
<i>Board and Slabs</i>						
Cellular glass	8.0	0.33	—	3.03	—	0.18
Glass fiber, organic bonded	4.0–9.0	0.25	—	4.00	—	0.23
Expanded perlite, organic bonded	1.0	0.36	—	2.78	—	0.30
Expanded rubber (rigid)	4.5	0.22	—	4.55	—	0.40
Expanded polystyrene, extruded (smooth skin surface) (CFC-12 exp.)	1.8–3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, extruded (smooth skin surface) (HCFC-142b exp.) ^h	1.8–3.5	0.20	—	5.00	—	0.29

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values^a (Continued)

Description	Density, lb/ft ³	Conductivity ^b (k), Btu·in h·ft ² ·°F	Conductance (C), Btu h·ft ² ·°F	Resistance ^c (R)		Specific Heat, Btu lb·°F
				Per Inch Thickness (1/k), °F·ft ² ·h Btu·in	For Thickness Listed (1/C), °F·ft ² ·h Btu	
Expanded polystyrene, molded beads	1.0 1.25 1.5 1.75 2.0	0.26 0.25 0.24 0.24 0.23	— — — — —	3.85 4.00 4.17 4.17 4.35	— — — — —	— — — — —
Cellular polyurethane/polyisocyanurate ⁱ (CFC-11 exp.) (unfaced)	1.5	0.16-0.18	—	6.25-5.56	—	0.38
Cellular polyisocyanurate ⁱ (CFC-11 exp.) (gas-permeable facers)	1.5-2.5	0.16-0.18	—	6.25-5.56	—	0.22
Cellular polyisocyanurate ⁱ (CFC-11 exp.) (gas-impermeable facers)	2.0	0.14	—	7.04	—	0.22
Cellular phenolic (closed cell)(CFC-11, CFC-113 exp.)	3.0	0.12	—	8.20	—	—
Cellular phenolic (open cell)	1.8-2.2	0.23	—	4.40	—	—
Mineral fiber with resin binder	15.0	0.29	—	3.45	—	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16-17	0.34	—	2.94	—	—
Acoustical tile	18.0	0.35	—	2.86	—	0.19
Acoustical tile	21.0	0.37	—	2.70	—	—
Mineral fiberboard, wet molded						
Acoustical tile ^k	23.0	0.42	—	2.38	—	0.14
Wood or cane fiberboard						
Acoustical tile, ^k 0.5 in.	—	—	0.80	—	1.25	0.31
Acoustical tile ^k , 0.75 in.	—	—	0.53	—	1.89	—
Interior finish (plank, tile)	15.0	0.35	—	2.86	—	0.32
Cement fiber slabs (shredded wood with Portland cement binder)	25-27.0	0.50-0.53	—	2.0-1.89	—	—
Cement fiber slabs (shredded wood with magnesia oxysulfide binder)	22.0	0.57	—	1.75	—	0.31
<i>Loose Fill</i>						
Cellulosic insulation (milled paper or wood pulp)	2.3-3.2	0.27-0.32	—	3.70-3.13	—	0.33
Perlite, expanded	2.0-4.1 4.1-7.4 7.4-11.0	0.27-0.31 0.31-0.36 0.36-0.42	— — —	3.7-3.3 3.3-2.8 2.8-2.4	— — —	0.26 — —
Mineral fiber (rock, slag, or glass) ^g						
approx. 3.75-5 in.	0.6-2.0	—	—	—	11.0	0.17
approx. 6.5-8.75 in.	0.6-2.0	—	—	—	19.0	—
approx. 7.5-10 in.	0.6-2.0	—	—	—	22.0	—
approx. 10.25-13.75 in.	0.6-2.0	—	—	—	30.0	—
Mineral fiber (rock, slag, or glass) ^g approx. 3.5 in. (closed sidewall application)	2.0-3.5	—	—	—	12.0-14.0	—
Vermiculite, exfoliated	7.0-8.2 4.0-6.0	0.47 0.44	— —	2.13 2.27	— —	0.32 —
<i>Spray Applied</i>						
Polyurethane foam	1.5-2.5	0.16-0.18	—	6.25-5.56	—	—
Ureaformaldehyde foam	0.7-1.6	0.22-0.28	—	4.55-3.57	—	—
Cellulosic fiber	3.5-6.0	0.29-0.34	—	3.45-2.94	—	—
Glass fiber	3.5-4.5	0.26-0.27	—	3.85-3.70	—	—
METALS (See Chapter 36, Table 3)						
ROOFING						
Asbestos-cement shingles	120	—	4.76	—	0.21	0.24
Asphalt roll roofing	70	—	6.50	—	0.15	0.36
Asphalt shingles	70	—	2.27	—	0.44	0.30
Built-up roofing	0.375 in. 70	— —	3.00	—	0.33	0.35
Slate	0.5 in.	—	20.00	—	0.05	0.30
Wood shingles, plain and plastic film faced	—	—	1.06	—	0.94	0.31
PLASTERING MATERIALS						
Cement plaster, sand aggregate	116	5.0	—	0.20	—	0.20
Sand aggregate	0.375 in.	—	13.3	—	0.08	0.20
Sand aggregate	0.75 in.	—	6.66	—	0.15	0.20
Gypsum plaster:						
Lightweight aggregate	0.5 in.	45	3.12	—	0.32	—
Lightweight aggregate	0.625 in.	45	2.67	—	0.39	—
Lightweight aggregate on metal lath	0.75 in.	—	2.13	—	0.47	—
Perlite aggregate	45	1.5	—	0.67	—	0.32
Sand aggregate	105	5.6	—	0.18	—	0.20
Sand aggregate	0.5 in.	105	11.10	—	0.09	—
Sand aggregate	0.625 in.	105	9.10	—	0.11	—
Sand aggregate on metal lath	0.75 in.	—	7.70	—	0.13	—
Vermiculite aggregate	45	1.7	—	0.59	—	—
MASONRY MATERIALS						
<i>Masonry Units</i>						
Brick, fired clay	150 140 130 120 110	8.4-10.2 7.4-9.0 6.4-7.8 5.6-6.8 4.9-5.9	— — — — —	0.12-0.10 0.14-0.11 0.16-0.12 0.18-0.15 0.20-0.17	— — — — —	— — — 0.19 —

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values^a (Continued)

Description	Density, lb/ft ³	Conductivity ^b		Resistance ^c (R)		Specific Heat, Btu lb·°F
		(k), Btu·in h·ft ² ·°F	Conductance (C), Btu h·ft ² ·°F	Per Inch	For Thickness	
				Thickness (1/k), °F·ft ² ·h Btu·in	Listed (1/C), °F·ft ² ·h Btu	
Brick, fired clay <i>continued</i>	100	4.2-5.1	—	0.24-0.20	—	—
	90	3.6-4.3	—	0.28-0.24	—	—
	80	3.0-3.7	—	0.33-0.27	—	—
	70	2.5-3.1	—	0.40-0.33	—	—
Clay tile, hollow						
1 cell deep 3 in.	—	—	1.25	—	0.80	0.21
1 cell deep 4 in.	—	—	0.90	—	1.11	—
2 cells deep 6 in.	—	—	0.66	—	1.52	—
2 cells deep 8 in.	—	—	0.54	—	1.85	—
2 cells deep 10 in.	—	—	0.45	—	2.22	—
3 cells deep 12 in.	—	—	0.40	—	2.50	—
Concrete blocks ¹						
Limestone aggregate						
8 in., 36 lb, 138 lb/ft ³ concrete, 2 cores	—	—	—	—	—	—
Same with perlite filled cores	—	—	0.48	—	2.1	—
12 in., 55 lb, 138 lb/ft ³ concrete, 2 cores	—	—	—	—	—	—
Same with perlite filled cores	—	—	0.27	—	3.7	—
Normal weight aggregate (sand and gravel)						
8 in., 33-36 lb, 126-136 lb/ft ³ concrete, 2 or 3 cores	—	—	0.90-1.03	—	1.11-0.97	0.22
Same with perlite filled cores	—	—	0.50	—	2.0	—
Same with verm. filled cores	—	—	0.52-0.73	—	1.92-1.37	—
12 in., 50 lb, 125 lb/ft ³ concrete, 2 cores	—	—	0.81	—	1.23	0.22
Medium weight aggregate (combinations of normal weight and lightweight aggregate)						
8 in., 26-29 lb, 97-112 lb/ft ³ concrete, 2 or 3 cores	—	—	0.58-0.78	—	1.71-1.28	—
Same with perlite filled cores	—	—	0.27-0.44	—	3.7-2.3	—
Same with verm. filled cores	—	—	0.30	—	3.3	—
Same with molded EPS (beads) filled cores	—	—	0.32	—	3.2	—
Same with molded EPS inserts in cores	—	—	0.37	—	2.7	—
Lightweight aggregate (expanded shale, clay, slate or slag, pumice)						
6 in., 16-17 lb 85-87 lb/ft ³ concrete, 2 or 3 cores	—	—	0.52-0.61	—	1.93-1.65	—
Same with perlite filled cores	—	—	0.24	—	4.2	—
Same with verm. filled cores	—	—	0.33	—	3.0	—
8 in., 19-22 lb, 72-86 lb/ft ³ concrete,	—	—	0.32-0.54	—	3.2-1.90	0.21
Same with perlite filled cores	—	—	0.15-0.23	—	6.8-4.4	—
Same with verm. filled cores	—	—	0.19-0.26	—	5.3-3.9	—
Same with molded EPS (beads) filled cores	—	—	0.21	—	4.8	—
Same with UF foam filled cores	—	—	0.22	—	4.5	—
Same with molded EPS inserts in cores	—	—	0.29	—	3.5	—
12 in., 32-36 lb, 80-90 lb/ft ³ concrete, 2 or 3 cores	—	—	0.38-0.44	—	2.6-2.3	—
Same with perlite filled cores	—	—	0.11-0.16	—	9.2-6.3	—
Same with verm. filled cores	—	—	0.17	—	5.8	—
Stone, lime, or sand						
Quartzitic and sandstone	180	72	—	0.01	—	—
	160	43	—	0.02	—	—
	140	24	—	0.04	—	—
	120	13	—	0.08	—	0.19
Calclitic, dolomitic, limestone, marble, and granite	180	30	—	0.03	—	—
	160	22	—	0.05	—	—
	140	16	—	0.06	—	—
	120	11	—	0.09	—	0.19
	100	8	—	0.13	—	—
Gypsum partition tile						
3 by 12 by 30 in., solid	—	—	0.79	—	1.26	0.19
3 by 12 by 30 in., 4 cells	—	—	0.74	—	1.35	—
4 by 12 by 30 in., 3 cells	—	—	0.60	—	1.67	—
Concretes						
Sand and gravel or stone aggregate concretes (concretes with more than 50% quartz or quartzite sand have conductivities in the higher end of the range)	150	10.0-20.0	—	0.10-0.05	—	—
	140	9.0-18.0	—	0.11-0.06	—	0.19-0.24
	130	7.0-13.0	—	0.14-0.08	—	—
Limestone concretes	140	11.1	—	0.09	—	—
	120	7.9	—	0.13	—	—
	100	5.5	—	0.18	—	—
Gypsum-fiber concrete (87.5% gypsum, 12.5% wood chips)	51	1.66	—	0.60	—	0.21
Cement/lime, mortar, and stucco	120	9.7	—	0.10	—	—
	100	6.7	—	0.15	—	—
	80	4.5	—	0.22	—	—
Lightweight aggregate concretes						
Expanded shale, clay, or slate; expanded slags; cinders; pumice (with density up to 100 lb/ft ³); and scoria (sanded concretes have conductivities in the higher end of the range)	120	6.4-9.1	—	0.16-0.11	—	—
	100	4.7-6.2	—	0.21-0.16	—	0.20
	80	3.3-4.1	—	0.30-0.24	—	0.20
	60	2.1-2.5	—	0.48-0.40	—	—
	40	1.3	—	0.78	—	—

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values^a (Concluded)

Description	Density, lb/ft ³	Conductivity ^b (<i>k</i>), Btu·in h·ft ² ·°F	Conductance (<i>C</i>), Btu h·ft ² ·°F	Resistance ^c (<i>R</i>)		Specific Heat, Btu lb·°F
				Per Inch Thickness (1/ <i>k</i>), °F·ft ² ·h Btu·in	For Thickness Listed (1/ <i>C</i>), °F·ft ² ·h Btu	
Perlite, vermiculite, and polystyrene beads	50	1.8–1.9	—	0.55–0.53	—	—
	40	1.4–1.5	—	0.71–0.67	—	0.15–0.23
	30	1.1	—	0.91	—	—
	20	0.8	—	1.25	—	—
Foam concretes	120	5.4	—	0.19	—	—
	100	4.1	—	0.24	—	—
	80	3.0	—	0.33	—	—
	70	2.5	—	0.40	—	—
Foam concretes and cellular concretes	60	2.1	—	0.48	—	—
	40	1.4	—	0.71	—	—
	20	0.8	—	1.25	—	—

SIDING MATERIALS (on flat surface)

Shingles

Asbestos-cement	120	—	4.75	—	0.21	—
Wood, 16 in., 7.5 exposure	—	—	1.15	—	0.87	0.31
Wood, double, 16-in., 12-in. exposure	—	—	0.84	—	1.19	0.28
Wood, plus insul. backer board, 0.3125 in.	—	—	0.71	—	1.40	0.31

Siding

Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	0.21	0.24
Asphalt roll siding	—	—	6.50	—	0.15	0.35
Asphalt insulating siding (0.5 in. bed.)	—	—	0.69	—	1.46	0.35
Hardboard siding, 0.4375 in.	—	—	1.49	—	0.67	0.28
Wood, drop, 1 by 8 in.	—	—	1.27	—	0.79	0.28
Wood, bevel, 0.5 by 8 in., lapped	—	—	1.23	—	0.81	0.28
Wood, bevel, 0.75 by 10 in., lapped	—	—	0.95	—	1.05	0.28
Wood, plywood, 0.375 in., lapped	—	—	1.59	—	0.59	0.29
Aluminum or Steel ^m , over sheathing	—	—	—	—	—	—
Hollow-backed	—	—	1.61	—	0.61	0.29
Insulating-board backed nominal 0.375 in.	—	—	0.55	—	1.82	0.32
Insulating-board backed nominal 0.375 in., foil backed	—	—	0.34	—	2.96	—
Architectural (soda-lime float) glass	158	6.9	—	—	—	0.21

WOODS (12% moisture content)^{e,m}

Hardwoods

Oak	41.2–46.8	1.12–1.25	—	0.89–0.80	—	0.39 ^o
Birch	42.6–45.4	1.16–1.22	—	0.87–0.82	—	—
Maple	39.8–44.0	1.09–1.19	—	0.92–0.84	—	—
Ash	38.4–41.9	1.06–1.14	—	0.94–0.88	—	—

Softwoods

Southern Pine	35.6–41.2	1.00–1.12	—	1.00–0.89	—	0.39 ^o
Douglas Fir-Larch	33.5–36.3	0.95–1.01	—	1.06–0.99	—	—
Southern Cypress	31.4–32.1	0.90–0.92	—	1.11–1.09	—	—
Hem-Fir, Spruce-Pine-Fir	24.5–31.4	0.74–0.90	—	1.35–1.11	—	—
West Coast Woods, Cedars	21.7–31.4	0.68–0.90	—	1.48–1.11	—	—
California Redwood	24.5–28.0	0.74–0.82	—	1.35–1.22	—	—

^aValues are for a mean temperature of 75°F. Representative values for dry materials are intended as design (not specification) values for materials in normal use. Thermal values of insulating materials may differ from design values depending on their in-situ properties (e.g., density and moisture content, orientation, etc.) and variability experienced during manufacture. For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

^bTo obtain thermal conductivities in Btu/h·ft·°F, divide the *k*-factor by 12 in./ft.

^cResistance values are the reciprocals of *C* before rounding off *C* to two decimal places.

^dLewis (1967).

^eU.S. Department of Agriculture (1974).

^fDoes not include paper backing and facing, if any. Where insulation forms a boundary (reflective or otherwise) of an airspace, see Tables 2 and 3 for the insulating value of an airspace with the appropriate effective emittance and temperature conditions of the space.

^gConductivity varies with fiber diameter. (See Chapter 20, Factors Affecting Thermal Performance.) Batt, blanket, and loose-fill mineral fiber insulations are manufactured to achieve specified R-values, the most common of which are listed in the table. Due to differences in manufacturing processes and materials, the product thicknesses, densities, and thermal conductivities vary over considerable ranges for a specified R-value.

^hThis material is relatively new and data are based on limited testing.

ⁱFor additional information, see Society of Plastics Engineers (SPI) *Bulletin* U108. Values are for aged, unfaced board stock. For change in conductivity with age of expanded polyurethane/polyisocyanurate, see Chapter 20, Factors Affecting Thermal Performance.

^jValues are for aged products with gas-impermeable facers on the two major surfaces. An aluminum foil facer of 0.001 in. thickness or greater is generally considered impermeable to gases. For change in conductivity with age of expanded polyisocyanurate, see Chapter 20, Factors Affecting Thermal Performance, and SPI *Bulletin* U108.

^kInsulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.

^lValues for fully grouted block may be approximated using values for concrete with a similar unit weight.

^mValues for metal siding applied over flat surfaces vary widely, depending on amount of ventilation of airspace beneath the siding; whether airspace is reflective of non-reflective; and on thickness, type, and application of insulating backing-board used. Values given are averages for use as design guides, and were obtained from several guarded hot box tests (ASTM C236) or calibrated hot box (ASTM C976) on hollow-backed types and types made using backing-boards of wood fiber, foamed plastic, and glass fiber. Departures of ±50% or more from the values given may occur.

ⁿSee Adams (1971), MacLean (1941), and Wilkes (1979). The conductivity values listed are for heat transfer across the grain. The thermal conductivity of wood varies linearly with the density, and the density ranges listed are those normally found for the wood species given. If the density of the wood species is not known, use the mean conductivity value. For extrapolation to other moisture contents, the following empirical equation developed by Wilkes (1979) may be used:

$$k = 0.1791 + \frac{(1.874 \times 10^{-2} + 5.753 \times 10^{-4}M)\rho}{1 + 0.01M}$$

where ρ is density of the moist wood in lb/ft³, and M is the moisture content in percent.

^oFrom Wilkes (1979), an empirical equation for the specific heat of moist wood at 75°F is as follows:

$$c_p = \frac{(0.299 + 0.01M)}{(1 + 0.01M)} + \Delta c_p$$

where Δc_p accounts for the heat of sorption and is denoted by

$$\Delta c_p = M(1.921 \times 10^{-3} - 3.168 \times 10^{-5}M)$$

where M is the moisture content in percent by mass.

If the steel framing is accounted for using the parallel flow method, the C-factor of the wall is determined using Equation (5) from Chapter 20 as follows:

$$C_{av} = (0.92 \times 0.084) + (0.08 \times 0.629)$$

$$= 0.128 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

$$R_{T(av)} = 7.81 ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$

If the steel framing is included using the isothermal planes method, the C-factor of the wall is determined using Equations (2) and (3) from Chapter 20 as follows:

$$R_{T(av)} = 0.45 + 1/[(0.92/11.00) + (0.08/0.69)] + 0.45$$

$$= 5.91 ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$$

$$C_{av} = 0.169 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

For this insulated steel frame wall, Farouk and Larson (1983) measured an average R-value of $6.61 ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$.

In ASHRAE/IES *Standard* 90.1-1989, Energy Efficient Design of New Buildings except New Low-Rise Residential Buildings, one method given for determining the thermal resistance of wall assemblies containing metal framing involves using a parallel path correction factor F_c . The F_c values are included in Table 8C-2 of ASHRAE/IES *Standard* 90.1-1989. For 2 by 4 steel framing, 16 in. on center, $F_c = 0.50$. Using the correction factor method, an R-value of $6.40 ^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h/Btu}$ [$0.45 + 11(0.50) + 0.45$] is obtained for the wall described in Example 3.

Zone Method of Calculation

For structures with widely spaced metal members of substantial cross-sectional area, calculation by the isothermal planes method can result in thermal resistance values that are too low. For these constructions, the *zone method* can be used. This method involves two separate computations—one for a chosen limited portion, Zone A, containing the highly conductive element; the other for the remaining portion of simpler construction, Zone B. The two computations are then combined using the parallel flow method, and the average transmittance per unit overall area is calculated. The basic laws of heat transfer are applied by adding the area conductances CA of elements in parallel, and adding area resistances R/A of elements in series.

The surface shape of Zone A is determined by the metal element. For a metal beam (see Figure 5), the Zone A surface is a strip of width W that is centered on the beam. For a rod perpendicular to panel surfaces, it is a circle of diameter W . The value of W is calculated from Equation (1), which is empirical. The value of d should not be less than 0.5 in. for still air.

$$W = m + 2d \tag{1}$$

where

- m = width or diameter of metal heat path terminal, in.
- d = distance from panel surface to metal, in.

Generally, the value of W should be calculated using Equation (1) for each end of the metal heat path; the larger value, within the limits of the basic area, should be used as illustrated in Example 4.

Example 4. Calculate transmittance of the roof deck shown in Figure 5. Tee-bars at 24 in. OC support glass fiber form boards, gypsum concrete, and built-up roofing. Conductivities of components are: steel, 314.4 Btu·in/h·ft²·°F; gypsum concrete, 1.66 Btu·in/h·ft²·°F; and glass fiber form board, 0.25 Btu·in/h·ft²·°F. Conductance of built-up roofing is 3.00 Btu/h·ft²·°F.

Solution: The basic area is 2 ft² (24 in. by 12 in.) with a tee-bar (12 in. long) across the middle. This area is divided into Zones A and B.

Zone A is determined from Equation (1) as follows:

$$\text{Top side } W = m + 2d = 0.625 + (2 \times 1.5) = 3.625 \text{ in.}$$

$$\text{Bottom side } W = m + 2d = 2.0 + (2 \times 0.5) = 3.0 \text{ in.}$$

Using the larger value of W , the area of Zone A is $(12 \times 3.625)/144 = 0.302 \text{ ft}^2$. The area of Zone B is $2.0 - 0.302 = 1.698 \text{ ft}^2$.

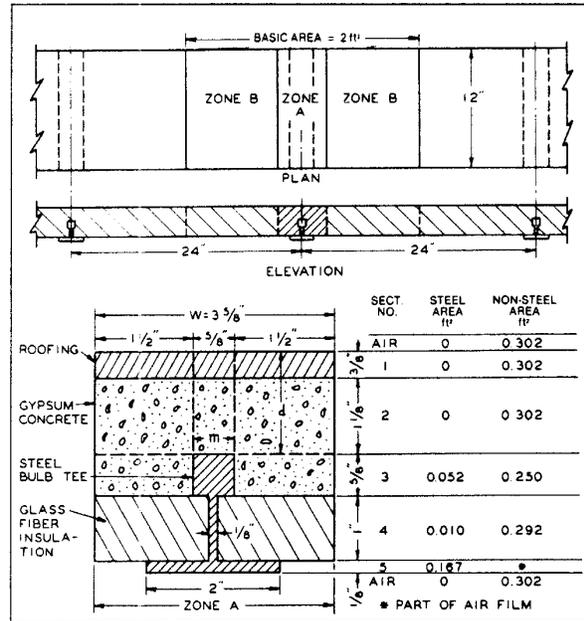


Fig. 5 Gypsum Roof Deck on Bulb Tees (Example 4)

To determine area transmittance for Zone A, divide the structure within the zone into five sections parallel to the top and bottom surfaces (Figure 5). The area conductance CA of each section is calculated by adding the area conductances of its metal and nonmetal paths. Area conductances of the sections are converted to area resistances R/A and added to obtain the total resistance of Zone A.

Section	Area × Conductance	CA	$\frac{1}{CA} = \frac{R}{A}$
Air (outside, 15 mph)	0.302×6.00	1.81	0.55
No. 1, Roofing	0.302×3.00	0.906	1.10
No. 2, Gypsum concrete	$0.302 \times 1.66/1.125$	0.446	2.24
No. 3, Steel	$0.052 \times 314.4/0.625$	26.2	0.04
No. 3, Gypsum concrete	$0.250 \times 1.66/0.625$	0.664	
No. 4, Steel	$0.010 \times 314.4/1.00$	3.14	0.31
No. 4, Glass fiberboard	$0.292 \times 0.25/1.00$	0.073	
No. 5, Steel	$0.167 \times 314.4/0.125$	420.0	0.002
Air (inside)	0.302×1.63	0.492	2.03
Total $R/A = 6.27$			

Area transmittance of Zone A = $1/(R/A) = 1/6.27 = 0.159$.

For Zone B, the unit resistances are added and then converted to area transmittance, as shown in the following table.

Section	Resistance, R
Air (outside, 15 mph)	$1/6.00 = 0.17$
Roofing	$1/3.00 = 0.33$
Gypsum concrete	$1.75/1.66 = 1.05$
Glass fiberboard	$1.00/0.25 = 4.00$
Air (inside)	$1/1.63 = 0.61$
Total resistance	$= 6.16$

Since unit transmittance = $1/R = 0.162$, the total area transmittance UA is calculated as follows:

$$\text{Zone B} = 1.698 \times 0.162 = 0.275$$

$$\text{Zone A} = 0.159$$

$$\text{Total area transmittance of basic area} = 0.434$$

$$\text{Transmittance per ft}^2 = 0.434/2.0 = 0.217$$

$$\text{Resistance per ft}^2 = 4.61$$

Overall R-values of 4.57 and 4.85 °F·ft²·h/Btu have been measured in two guarded hot box tests of a similar construction.

When the steel member represents a relatively large proportion of the total heat flow path, as in Example 4, detailed calculations of resistance in sections 3, 4, and 5 of Zone A are unnecessary; if only the steel member is considered, the final result of Example 4 is the same. However, if the heat flow path represented by the steel member is small, as for a tie rod, detailed calculations for sections 3, 4, and 5 are necessary. A panel with an internal metallic structure and bonded on one or both sides to a metal skin or covering presents special problems of lateral heat flow not covered in the zone method.

Ceilings and Roofs

The overall R-value for ceilings of wood frame flat roofs can be calculated using Equations (1) through (5) from Chapter 20. Properties of the materials are found in Tables 1, 2, 3, and 4. The fraction of framing is assumed to be 0.10 for joists at 16 in. OC and 0.07 for joists at 24 in. OC. The calculation procedure is similar to that shown in Example 1. Note that if the ceiling contains plane air spaces (see Table 2), the resistance depends on the direction of heat flow, *i.e.*, whether the calculation is for a winter (heat flow up) or summer (heat flow down) condition.

For ceilings of pitched roofs under winter conditions, calculate the R-value of the ceiling using the procedure for flat roofs. The heat loss from these ceilings can be obtained using a calculated attic temperature (see Chapter 25). Table 5 can be used to determine the effective resistance of the attic space under summer conditions for varying conditions of ventilation air temperature, airflow direction and rates, ceiling resistance, roof or sol-air temperatures, and surface emittances (Joy 1958).

The R-value is the total resistance obtained by adding the ceiling and effective attic resistances. The applicable temperature difference is that difference between room air and sol-air temperatures or between room air and roof temperatures (see Table 5, footnote f). Table 5 can be used for pitched and flat residential roofs over attic spaces. When an attic has a floor, the ceiling resistance should account for the complete ceiling-floor construction.

Windows and Doors

The U-factors given in Table 5 of Chapter 27 are for vertical glazing (*e.g.*, windows, glass in exterior doors, glass doors, and skylights). The values were computed using procedures outlined in Chapter 27. The U-factors in Table 6 are for exterior wood and steel doors. The values given for wood doors were calculated, and those for steel doors were taken from hot box tests (Sabine *et al.* 1975, Yellott 1965) or from manufacturers' test reports. An outdoor surface conductance of 6.0 Btu/h · ft² · °F was used, and the indoor surface conductance was taken as 1.46 Btu/h · ft² · °F for vertical surfaces with horizontal heat flow. All values given are for exterior doors without glazing. If an exterior door contains glazing, the glazing should be analyzed as a window, as illustrated in Example 5.

Example 5. Determine the U-factor of a fixed wood frame residential window containing double insulating glass with 0.5-in. air space and metal spacer for winter conditions.

Solution: From Chapter 27, Table 5, the U-factor of the center of the glass portion only is 0.49 Btu/h · ft² · °F for glazing 1D6, double glazing, 0.5-in. air space. The wood frame of the window must also be

Table 5 Effective Thermal Resistance of Ventilated Attics^a (Summer Condition)

		PART A. NONREFLECTIVE SURFACES									
		No Ventilation ^b		Natural Ventilation				Power Ventilation ^c			
		Ventilation Rate, cfm/ft ²									
		0		0.1 ^d		0.5		1.0		1.5	
		Ceiling Resistance R ^e , °F · ft ² · /Btu									
Ventilation Air Temperature, °F	Sol-Air ^f Temperature, °F	10	20	10	20	10	20	10	20	10	20
80	120	1.9	1.9	2.8	3.4	6.3	9.3	9.6	16	11	20
	140	1.9	1.9	2.8	3.5	6.5	10	9.8	17	12	21
	160	1.9	1.9	2.8	3.6	6.7	11	10	18	13	22
90	120	1.9	1.9	2.5	2.8	4.6	6.7	6.1	10	6.9	13
	140	1.9	1.9	2.6	3.1	5.2	7.9	7.6	12	8.6	15
	160	1.9	1.9	2.7	3.4	5.8	9.0	8.5	14	10	17
100	120	1.9	1.9	2.2	2.3	3.3	4.4	4.0	6.0	4.1	6.9
	140	1.9	1.9	2.4	2.7	4.2	6.1	5.8	8.7	6.5	10
	160	1.9	1.9	2.6	3.2	5.0	7.6	7.2	11	8.3	13
		PART B. REFLECTIVE SURFACES ^g									
80	120	6.5	6.5	8.1	8.8	13	17	17	25	19	30
	140	6.5	6.5	8.2	9.0	14	18	18	26	20	31
	160	6.5	6.5	8.3	9.2	15	18	19	27	21	32
90	120	6.5	6.5	7.5	8.0	10	13	12	17	13	19
	140	6.5	6.5	7.7	8.3	12	15	14	20	16	22
	160	6.5	6.5	7.9	8.6	13	16	16	22	18	25
100	120	6.5	6.5	7.0	7.4	8.0	10	8.5	12	8.8	12
	140	6.5	6.5	7.3	7.8	10	12	11	15	12	16
	160	6.5	6.5	7.6	8.2	11	14	13	18	15	20

^aAlthough the term effective resistance is commonly used when there is attic ventilation, this table includes values for situations with no ventilation. The effective resistance of the attic added to the resistance (1/U) of the ceiling yields the effective resistance of this combination based on sol-air (see Chapter 26) and room temperatures. These values apply to wood frame construction with a roof deck and roofing that has a conductance of 1.0 Btu/h · ft² · °F.

^bThis condition cannot be achieved in the field unless extreme measures are taken to tightly seal the attic.

^cBased on air discharging outward from attic.

^dWhen attic ventilation meets the requirements stated in Chapter 23, 0.1 cfm/ft² is assumed as the natural summer ventilation rate.

^eWhen determining ceiling resistance, do not add the effect of a reflective surface facing the attic, as it is accounted for in Table 5, Part B.

^fRoof surface temperature rather than sol-air temperature (see Chapter 26) can be used if 0.25 is subtracted from the attic resistance shown.

^gSurfaces with effective emittance ε_{eff} = 0.05 between ceiling joists facing attic space.

Table 6 Transmission Coefficients U for Wood and Steel Doors, $\text{Btu}/\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$

Nominal Door Thickness, in.	Description	No Storm Door	Wood Storm Door ^c	Metal Storm Door ^d
Wood Doors^{a,b}				
1-3/8	Panel door with 7/16-in. panels ^e	0.57	0.33	0.37
1-3/8	Hollow core flush door	0.47	0.30	0.32
1-3/8	Solid core flush door	0.39	0.26	0.28
1-3/4	Panel door with 7/16-in. panels ^e	0.54	0.32	0.36
1-3/4	Hollow core flush door	0.46	0.29	0.32
1-3/4	Panel door with 1-1/8-in. panels ^e	0.39	0.26	0.28
1-3/4	Solid core flush door	0.40	—	0.26
2-1/4	Solid core flush door	0.27	0.20	0.21
Steel Doors^b				
1-3/4	Fiberglass or mineral wool core with steel stiffeners, no thermal break ^f	0.60	—	—
1-3/4	Paper honeycomb core without thermal break ^f	0.56	—	—
1-3/4	Solid urethane foam core without thermal break ^a	0.40	—	—
1-3/4	Solid fire rated mineral fiberboard core without thermal break ^f	0.38	—	—
1-3/4	Polystyrene core without thermal break (18 gage commercial steel) ^f	0.35	—	—
1-3/4	Polyurethane core without thermal break (18 gage commercial steel) ^f	0.29	—	—
1-3/4	Polyurethane core without thermal break (24 gage residential steel) ^f	0.29	—	—
1-3/4	Polyurethane core with thermal break and wood perimeter (24 gage residential steel) ^f	0.20	—	—
1-3/4	Solid urethane foam core with thermal break ^a	0.20	—	0.16

Note: All U -factors for exterior doors in this table are for doors with no glazing, except for the storm doors which are in addition to the main exterior door. Any glazing area in exterior doors should be included with the appropriate glass type and analyzed as a window (see Chapter 27). Interpolation and moderate extrapolation are permitted for door thicknesses other than those specified.

^aValues are based on a nominal 32 by 80 in. door size with no glazing.

^bOutside air conditions: 15 mph wind speed, 0°F air temperature; inside air conditions: natural convection, 70°F air temperature.

^cValues for wood storm door are for approximately 50% glass area.

^dValues for metal storm door are for any percent glass area.

^e55% panel area.

^fASTM C 236 hotbox data on a nominal 3 by 7 ft door size with no glazing.

considered when determining the window U -factor. Referring to Table 5 in Chapter 27, for a fixed wood frame window with a 0.5-in. air space and metal spacer, the U -factor is given as 0.51 $\text{Btu}/\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$.

All R -values are approximate, since a significant portion of the resistance of a window or door is contained in the air film resistances, and some parameters that may have important effects are not considered. For example, the listed U -factors assume the surface temperatures of surrounding bodies are equal to the ambient air temperature. However, the indoor surface of a window or door in an actual installation may be exposed to nearby radiating surfaces, such as radiant heating panels, or opposite walls with much higher or lower temperatures than the indoor air. Air movement across the indoor surface of a window or door, such as that caused by nearby heating and cooling outlet grilles, increases the U -factor; and air movement (wind) across the outdoor surface of a window or door also increases the U -factor.

U_o Concept

In Section 4 of ASHRAE *Standard* 90A-1980, Energy Conservation in New Building Design, requirements are stated in terms of U_o , where U_o is the combined thermal transmittance of the respective areas of gross exterior wall, roof or ceiling or both, and floor assemblies. The U_o equation for a wall is as follows:

$$U_o = (U_{\text{wall}} A_{\text{wall}} + U_{\text{window}} A_{\text{window}} + U_{\text{door}} A_{\text{door}}) / A_o \quad (2)$$

where

- U_o = average thermal transmittance of gross wall area
- A_o = gross area of exterior walls
- U_{wall} = thermal transmittance of all elements of opaque wall area
- A_{wall} = opaque wall area
- U_{window} = thermal transmittance of window area (including frame)

- A_{window} = window area (including frame)
- U_{door} = thermal transmittance of door area
- A_{door} = door area

Where more than one type of wall, window, or door is used, the U_o term for that exposure should be expanded into its subelements, as shown in Equation (3).

$$U_o A_o = U_{\text{wall } 1} A_{\text{wall } 1} + U_{\text{wall } 2} A_{\text{wall } 2} + \dots + U_{\text{wall } m} A_{\text{wall } m} \\ + U_{\text{window } 1} A_{\text{window } 1} + U_{\text{window } 2} A_{\text{window } 2} + \dots \\ + U_{\text{window } n} A_{\text{window } n} + U_{\text{door } 1} A_{\text{door } 1} \\ + U_{\text{door } 2} A_{\text{door } 2} + \dots + U_{\text{door } o} A_{\text{door } o} \quad (3)$$

Example 6. Calculate U_o for a wall 30 ft by 8 ft, constructed as in Example 1A. The wall contains one window 60 in. by 34 in. and a second window 36 in. by 30 in. Both windows are constructed as in Example 5. The wall also contains a 1.75-in. solid core flush door with a metal storm door 34 in. by 80 in. ($U = 0.26 \text{ Btu}/\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$ from Table 6).

Solution: The U -factors for the wall and windows were obtained in Examples 1A and 5, respectively. The areas of the different components are:

$$A_{\text{window}} = [(60 \times 34) + (36 \times 30)] / 144 = 21.7 \text{ ft}^2 \\ A_{\text{door}} = (34 \times 80) / 144 = 18.9 \text{ ft}^2 \\ A_{\text{wall}} = (30 \times 8) - (21.7 + 18.9) = 199.4 \text{ ft}^2$$

Therefore, the combined thermal transmittance for the wall is:

$$U_o = \frac{(0.063 \times 199.4) + (0.51 \times 21.7) + (0.26 \times 18.9)}{(30 \times 8)} \\ = 0.119 \text{ Btu}/\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

Slab-on-Grade and Below-Grade Construction

Heat transfer through basement walls and floors to the ground depends on the following factors: (1) the difference between the air temperature within the room and that of the ground and outside air, (2) the material of the walls or floor, and (3) the thermal

conductivity of the surrounding earth. The latter varies with local conditions and is usually unknown. Because of the great thermal inertia of the surrounding soil, ground temperature varies with depth, and there is a substantial time lag between changes in outdoor air temperatures and corresponding changes in ground temperatures. As a result, ground-coupled heat transfer is less amenable to steady-state representation than above-grade building elements. However, several simplified procedures for estimating ground-coupled heat transfer have been developed. These fall into two principal categories: (1) those that reduce the ground heat transfer problem to a closed form solution, and (2) those that use simple regression equations developed from statistically reduced multidimensional transient analyses.

Closed form solutions, including the ASHRAE arc-length procedure discussed in Chapter 25 by Latta and Boileau (1969), generally reduce the problem to one-dimensional, steady-state heat transfer. These procedures use simple, "effective" U-factors or ground temperatures or both. Methods differ in the various parameters averaged or manipulated to obtain these effective values. Closed form solutions provide acceptable results in climates that have a single dominant season, because the dominant season persists long enough to permit a reasonable approximation of steady-state conditions at shallow depths. The large errors (percentage) that are likely during transition seasons should not seriously affect building design decisions, since these heat flows are relatively insignificant when compared with those of the principal season.

The ASHRAE arc-length procedure is a reliable method for wall heat losses in cold winter climates. Chapter 25 discusses a slab-on-grade floor model developed by one study. Although both procedures give results comparable to transient computer solutions for cold climates, their results for warmer U.S. climates differ substantially.

Research conducted by Houghten *et al.* (1942) and Dill *et al.* (1945) indicates a heat flow of approximately 2.0 Btu/h · ft² through an uninsulated concrete basement floor with a temperature difference of 20 °F between the basement floor and the air 6 in. above it. A U-factor of 0.10 Btu/h · ft² · °F is sometimes used for concrete basement floors on the ground. For basement walls below grade, the temperature difference for winter design conditions is greater than for the floor. Test results indicate that at the midheight of the below-grade portion of the basement wall, the unit area heat loss is approximately twice that of the floor.

For concrete slab floors in contact with the ground at grade level, tests indicate that for small floor areas (equal to that of a 25 by 25 ft house) the heat loss can be calculated as proportional to the length of exposed edge rather than total area. This amounts

to 0.81 Btu/h per linear foot of exposed edge per °F difference between the indoor air temperature and the average outdoor air temperature. This value can be reduced appreciably by installing insulation under the ground slab and along the edge between the floor and abutting walls. In most calculations, if the perimeter loss is calculated accurately, no other floor losses need to be considered. Chapter 25 contains data for load calculations and heat loss values for below-grade walls and floors at different depths.

The second category of simplified procedures uses transient two-dimensional computer models to generate the ground heat transfer data that are then reduced to compact form by regression analysis (see Mitalas 1982 and 1983, Shipp 1983). These are the most accurate procedures available, but the database is very expensive to generate. In addition, these methods are limited to the range of climates and constructions specifically examined. Extrapolating beyond the outer bounds of the regression surfaces can produce significant errors.

Apparent Thermal Conductivity of Soil

Effective or apparent soil thermal conductivity is difficult to estimate precisely and may change substantially in the same soil at different times due to changed moisture conditions and the presence of freezing temperatures in the soil. Figure 6 shows the typical apparent soil thermal conductivity as a function of moisture content for different general types of soil. The figure is based on data presented in Salomone and Marlowe (1989) using envelopes of thermal behavior coupled with field moisture content ranges for different soil types. In Figure 6, the term well-graded applies to granular soils with good representation of all particle sizes from largest to smallest. The term poorly graded refers to granular soils with either a uniform gradation, in which most particles are about the same size, or a skip (or gap) gradation, in which particles of one or more intermediate sizes are not present.

Although thermal conductivity varies greatly over the complete range of possible moisture contents for a soil, this range can be narrowed if it is assumed that the moisture contents of most field soils lie between the "wilting point" of the soil (*i.e.*, the moisture content of a soil below which a plant cannot alleviate its wilting symptoms) and the "field capacity" of the soil (*i.e.*, the moisture

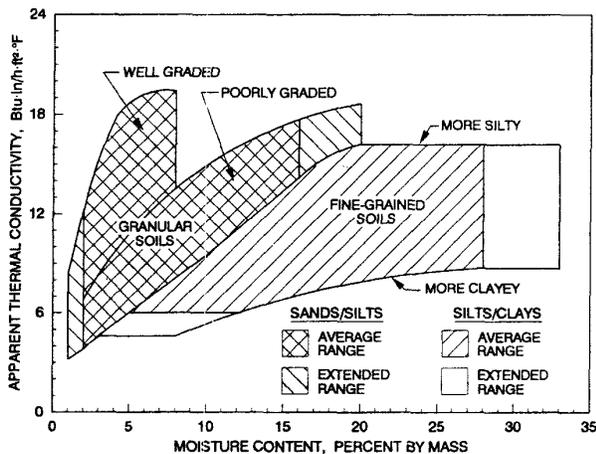


Fig. 6 Trends of Apparent Thermal Conductivity of Moist Soils

Table 7 Typical Apparent Thermal Conductivity Values for Soils, Btu · in/h · ft² · °F

	Normal Range	Recommended Values for Design ^a	
		Low ^b	High ^c
Sands	4.2 to 17.4	5.4	15.6
Silts	6 to 17.4	11.4	15.6
Clays	6 to 11.4	7.8	10.8
Loams	6 to 17.4	6.6	15.6

^aReasonable values for use when no site- or soil-specific data are available.

^bModerately conservative values for minimum heat loss through soil (*e.g.*, use in soil heat exchanger or earth-contact cooling calculations). Values are from Salomone and Marlowe (1989).

^cModerately conservative values for maximum heat loss through soil (*e.g.*, use in peak winter heat loss calculations). Values are from Salomone and Marlowe (1989).

Table 8 Typical Apparent Thermal Conductivity Values for Rocks, Btu · in/h · ft² · °F

	Normal Range
Pumice, tuff, obsidian	3.6 to 15.6
Basalt	3.6 to 18.0
Shale	6 to 27.6
Granite	12 to 30
Limestone, dolomite, marble	8.4 to 30
Quartzose sandstone	9.6 to 54

Table 9 Typical Water Vapor Permeance and Permeability Values for Common Building Materials^a

Material	Thickness, in.	Permeance, Perm	Resistance ^b , Rep	Permeability, Perm-in.	Resistance/in. ^b , Rep/in.
Construction Materials					
Concrete (1:2:4 mix)				3.2	0.31
Brick masonry	4	0.8 ^f	1.3		
Concrete block (cored, limestone aggregate)	8	2.4 ^f	0.4		
Tile masonry, glazed	4	0.12 ^f	8.3		
Asbestos cement board	0.12	4-8 ^d	0.1-0.2		
With oil-base finishes		0.3-0.5 ^d	2-3		
Plaster on metal lath	0.75	15 ^f	0.067		
Plaster on wood lath		11 ^e	0.091		
Plaster on plain gypsum lath (with studs)		20 ^f	0.050		
Gypsum wall board (plain)	0.375	50 ^f	0.020		
Gypsum sheathing (asphalt impregnated)	0.5			20 ^d	0.050
Structural insulating board (sheathing quality)				20-50 ^f	0.050-0.020
Structural insulating board (interior, uncoated)	0.5	50-90 ^f	0.020-0.011		
Hardboard (standard)	0.125	11 ^f	0.091		
Hardboard (tempered)	0.125	5 ^f	0.2		
Built-up roofing (hot mopped)		0.0			
Wood, sugar pine				0.4-5.4 ^b	2.5-0.19
Plywood (douglas fir, exterior glue)	0.25	0.7 ^f	1.4		
Plywood (douglas fir, interior glue)	0.25	1.9 ^f	0.53		
Acrylic, glass fiber reinforced sheet	0.056	0.12 ^d	8.3		
Polyester, glass fiber reinforced sheet	0.048	0.05 ^d	20		
Thermal Insulations					
Air (still)				120 ^f	0.0083
Cellular glass				0.0 ^d	∞
Corkboard				2.1-2.6 ^d	0.48-0.38
				9.5 ^e	0.11
Mineral wool (unprotected)				116 ^e	0.0086
Expanded polyurethane (R-11 blown) board stock				0.4-1.6 ^d	2.5-0.62
Expanded polystyrene—extruded				1.2 ^d	0.83
Expanded polystyrene—bead				2.0-5.8 ^d	0.50-0.17
Phenolic foam (covering removed)				26	0.038
Unicellular synthetic flexible rubber foam				0.02-0.15 ^d	50-6.7
Plastic and Metal Foils and Films^c					
Aluminum foil	0.001	0.0 ^d	∞		
Aluminum foil	0.00035	0.05 ^d	20		
Polyethylene	0.002	0.16 ^d	6.3		3100
Polyethylene	0.004	0.08 ^d	12.5		3100
Polyethylene	0.006	0.06 ^d	17		3100
Polyethylene	0.008	0.04 ^d	25		3100
Polyethylene	0.010	0.03 ^d	33		3100
Polyvinylchloride, unplasticized	0.002	0.68 ^d	1.5		
Polyvinylchloride, plasticized	0.004	0.8-1.4 ^d	1.3-0.72		
Polyester	0.001	0.73 ^d	1.4		
Polyester	0.0032	0.23 ^d	4.3		
Polyester	0.0076	0.08 ^d	12.5		
Cellulose acetate	0.01	4.6 ^d	0.2		
Cellulose acetate	0.125	0.32 ^d	3.1		

content of a soil that has been thoroughly wetted and then drained until the drainage rate has become negligibly small). After a prolonged dry spell, the moisture will be near the wilting point, and after a rainy period, the soil will have a moisture content near its field capacity. The moisture contents at these limits have been studied by many agricultural researchers, and data for different types of soil are given by Salomone and Marlowe (1989) and Kersten (1949). The shaded areas on Figure 6 approximate (1) the full range of moisture contents for different soil types and (2) a range between average values of each limit.

Table 7 gives a summary of design values for thermal conductivities of the basic soil classes. Table 8 gives ranges of thermal conductivity for some basic classes of rock. The value chosen depends on whether heat transfer is being calculated for minimum heat loss through the soil, as in a ground heat exchange system, or a maxi-

mum value, as in peak winter heat loss calculations for a basement. Hence, a high and a low value are given for each soil class.

As heat flows through the soil, the moisture tends to move away from the source of heat. This moisture migration provides initial mass transport of heat, but it also dries the soil adjacent to the heat source, hence lowering the apparent thermal conductivity in that zone of soil.

The following trends are typical in a soil when other factors are held constant:

1. k increases with moisture content
2. k increases with increasing dry density of a soil
3. k decreases with increasing organic content of a soil
4. k tends to decrease for soils with uniform gradations and rounded soil grains (because the grain-to-grain contacts are reduced)

Table 9 Typical Water Vapor Permeance and Permeability Values for Common Building Materials^a (Concluded)

Material	Weight, lb/100 ft ²	Permeance, Perms			Resistance ^h Rep		
		Dry-Cup	Wet-Cup	Other	Dry-Cup	Wet-Cup	Other
Building Paper, Felts, Roofing Papers^g							
Duplex sheet, asphalt laminated, aluminum foil one side	8.6	0.002	0.176		500	5.8	
Saturated and coated roll roofing	65	0.05	0.24		20	4.2	
Kraft paper and asphalt laminated, reinforced 30-120-30	6.8	0.3	1.8		3.3	0.55	
Blanket thermal insulation backup paper, asphalt coated	6.2	0.4	0.6-4.2		2.5	1.7-0.24	
Asphalt-saturated and coated vapor retarder paper	8.6	0.2-0.3	0.6		5.0-3.3	1.7	
Asphalt-saturated, but not coated, sheathing paper	4.4	3.3	20.2		0.3	0.05	
15-lb asphalt felt	14	1.0	5.6		1.0	0.18	
15-lb tar felt	14	4.0	18.2		0.25	0.055	
Single-kraft, double	3.2	31	42		0.032	0.024	
Liquid-Applied Coating Materials							
Thickness, in.							
Commercial latex paints (dry film thickness) ⁱ							
Vapor retarder paint	0.0031			0.45			2.22
Primer-sealer	0.0012			6.28			0.16
Vinyl acetate/acrylic primer	0.002			7.42			0.13
Vinyl-acrylic primer	0.0016			8.62			0.12
Semi-gloss vinyl-acrylic enamel	0.0024			6.61			0.15
Exterior acrylic house and trim	0.0017			5.47			0.18
Paint-2 coats							
Asphalt paint on plywood			0.4			2.5	
Aluminum varnish on wood		0.3-0.5			3.3-2.0		
Enamels on smooth plaster				0.5-1.5			2.0-0.66
Primers and sealers on interior insulation board				0.9-2.1			1.1-0.48
Various primers plus 1 coat flat oil paint on plaster				1.6-3.0			0.63-0.33
Flat paint on interior insulation board				4			0.25
Water emulsion on interior insulation board				30-85			0.03-0.012
Weight, oz/ft²							
Paint-3 coats							
Exterior paint, white lead and oil on wood siding		0.3-1.0			3.3-1.0		
Exterior paint, white lead-zinc oxide and oil on wood		0.9			1.1		
Styrene-butadiene latex coating	2	11			0.09		
Polyvinyl acetate latex coating	4	5.5			0.18		
Chlorosulfonated polyethylene mastic	3.5	1.7			0.59		
	7.0	0.06			16		
Asphalt cutback mastic, 1/16 in., dry		0.14			7.2		
3/16 in., dry		0.0			—		
Hot melt asphalt	2	0.5			2		
	3.5	0.1			10		

^aThis table permits comparisons of materials; but in the selection of vapor retarder materials, exact values for permeance or permeability should be obtained from the manufacturer or from laboratory tests. The values shown indicate variations among mean values for materials that are similar but of different density, orientation, lot, or source. The values should not be used as design or specification data. Values from dry-cup and wet-cup methods were usually obtained from investigations using ASTM E96 and C355; values shown under others were obtained by two-temperature, special cell, and air velocity methods. Permeance, resistance, permeability, and resistance per unit thickness values are given in the following units:

Permeance	Perm	= gr/h · ft ² · in. Hg
Resistance	Rep	= in. Hg · ft ² · h/gr
Permeability	Perm-in.	= gr/h · ft ² · (in. Hg/in.)
Resistance/unit thickness	Rep/in.	= (in. Hg · ft ² · h/gr)/in.

^bDepending on construction and direction of vapor flow.

^cUsually installed as vapor retarders, although sometimes used as exterior finish and elsewhere near cold side, where special considerations are then required for warm side barrier effectiveness.

^dDry-cup method.

^eWet-cup method.

^fOther than dry- or wet-cup method.

^gLow permeance sheets used as vapor retarders. High permeance used elsewhere in construction.

^hResistance and resistance/in. values have been calculated as the reciprocal of the permeance and permeability values.

ⁱCast at 10 mils wet film thickness.

5. *k* of a frozen soil may be higher or lower than that of the same unfrozen soil (because the conductivity of ice is higher than that of water but lower than that of the typical soil grains). Differences in *k* below moisture contents of 7 to 8% are quite small. At approximately 15% moisture content, differences in *k*-factors may vary up to 30% from unfrozen values.

When calculating annual energy use, values that represent typical site conditions as they vary during the year should be chosen. In climates where ground freezing is significant, accurate

heat transfer simulations should include the effect of the latent heat of fusion of water. The energy released during this phase change significantly retards the progress of the frost front in moist soils.

Water Vapor Transmission Data for Building Components

Table 9 gives typical water vapor permeance and permeability values for common building materials. These values can be used to calculate water vapor flow through building components and assemblies using Equations (14) through (17) in Chapter 20.

Table 10 Typical Thermal Conductivity k for Industrial Insulations at Various Mean Temperatures—Design Values^a

Material	Max. Temp., ^b °F	Typical Density, ^c lb/ft ³	Typical Conductivity k in Btu · in/h · ft ² · °F at Mean Temp., °F													
			-100	-75	-50	-25	0	25	50	75	100	200	300	500	700	900
BLANKETS AND FELTS																
ALUMINOSILICATE FIBER																
7 to 10 μ m diameter fiber	1800	4									0.24	0.32	0.54	0.99	1.03	
	2000	6-8									0.25	0.30	0.48	0.78	0.95	
3 μ m diameter fiber	2200	4									0.22	0.29	0.45	0.59	0.74	
MINERAL FIBER (Rock, slag, or glass)																
Blanket, metal reinforced	1200	6-12									0.26	0.32	0.39	0.54		
	1000	2.5-6									0.24	0.31	0.40	0.61		
Blanket, flexible, fine-fiber organic bonded	350	<0.75				0.25	0.26	0.28	0.30	0.33	0.36	0.53				
		0.75				0.24	0.25	0.27	0.29	0.32	0.34	0.48				
		1.0				0.23	0.24	0.25	0.27	0.29	0.32	0.43				
		1.5				0.21	0.22	0.23	0.25	0.27	0.28	0.37				
		2.0				0.20	0.21	0.22	0.23	0.25	0.26	0.33				
		3.0				0.19	0.20	0.21	0.22	0.23	0.24	0.31				
Blanket, flexible, textile fiber, organic bonded	350	0.65				0.27	0.28	0.29	0.30	0.31	0.32	0.50	0.68			
		0.75				0.26	0.27	0.28	0.29	0.31	0.32	0.48	0.66			
		1.0				0.24	0.25	0.26	0.27	0.29	0.31	0.45	0.60			
		1.5				0.22	0.23	0.24	0.25	0.27	0.29	0.39	0.51			
		3.0				0.20	0.21	0.22	0.23	0.24	0.25	0.32	0.41			
Felt, semirigid organic bonded	400	3-8							0.24	0.25	0.26	0.27	0.35	0.44		
	850	3	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.35	0.55			
Laminated and felted without binder	1200	7.5											0.35	0.45	0.60	
BLOCKS, BOARDS, AND PIPE INSULATION																
MAGNESIA																
85% CALCIUM SILICATE	1200	11-15									0.35	0.38	0.42			
	1800	12-15									0.38	0.41	0.44	0.52	0.62	0.72
CELLULAR GLASS	900	7.8-8.2	0.24	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.41	0.49	0.70	1.01	
DIATOMACEOUS SILICA	1600	21-22												0.64	0.68	0.72
	1900	23-25												0.70	0.75	0.80
MINERAL FIBER (Glass)																
Organic bonded, block and boards	400	3-10	0.16	0.17	0.18	0.19	0.20	0.22	0.24	0.25	0.26	0.33	0.40			
Nonpinking binder	1000	3-10									0.26	0.31	0.38	0.52		
Pipe insulation, slag, or glass	350	3-4					0.20	0.21	0.22	0.23	0.24	0.29				
	500	3-10					0.20	0.22	0.24	0.25	0.26	0.33	0.40			
Inorganic bonded block	1000	10-15									0.33	0.38	0.45	0.55		
	1800	15-24									0.32	0.37	0.42	0.52	0.62	0.74
Pipe insulation, slag, or glass	1000	10-15									0.33	0.38	0.45	0.55		
Resin binder		15	0.23	0.24	0.25	0.26	0.28	0.29								
RIGID POLYSTYRENE																
Extruded (CFC-12 exp.)																
(smooth skin surface)	165	1.8-3.5	0.16	0.16	0.17	0.16	0.17	0.18	0.19	0.20						
Molded beads	165	1	0.17	0.19	0.20	0.21	0.22	0.24	0.25	0.26	0.28					
		1.25	0.17	0.18	0.19	0.20	0.22	0.23	0.24	0.25	0.27					
		1.5	0.16	0.17	0.19	0.20	0.21	0.22	0.23	0.24	0.26					
		1.75	0.16	0.17	0.18	0.19	0.20	0.22	0.23	0.24	0.25					
		2.0	0.15	0.16	0.18	0.19	0.20	0.21	0.22	0.23	0.24					
RIGID POLYURETHANE/POLYISOCYANURATE^{c,d}																
Unfaced (CFC-11 exp.)	210	1.5-2.5	0.16	0.17	0.18	0.18	0.18	0.17	0.16	0.16	0.17					
RIGID POLYISOCYANURATE^c																
Gas-impermeable facers (CFC-11 exp.)	250	2.0							0.12	0.13	0.14	0.15				
RIGID PHENOLIC																
Closed cell (CFC-11, CFC-113 exp.)		3.0							0.11	0.115	0.12	0.125				
RUBBER, Rigid foamed	150	4.5							0.20	0.21	0.22	0.23				
VEGETABLE AND ANIMAL FIBER																
Wool felt (pipe insulation)	180	20							0.28	0.30	0.31	0.33				
INSULATING CEMENTS																
MINERAL FIBER (Rock, slag, or glass)																
With colloidal clay binder	1800	24-30									0.49	0.55	0.61	0.73	0.85	
With hydraulic setting binder	1200	30-40									0.75	0.80	0.85	0.95		
LOOSE FILL																
Cellulose insulation (milled pulverized paper or wood pulp)		2.5-3									0.26	0.27	0.29			
Mineral fiber, slag, rock, or glass		2-5				0.19	0.21	0.23	0.25	0.26	0.28	0.31				
Perlite (expanded)		3-5	0.22	0.24	0.25	0.27	0.28	0.30	0.31	0.33	0.35					
Silica aerogel		7.6				0.13	0.14	0.15	0.15	0.16	0.17	0.18				
Vermiculite (expanded)		7-8.2				0.39	0.40	0.42	0.44	0.45	0.47	0.49				
		4-6				0.34	0.35	0.38	0.40	0.42	0.44	0.46				

^aRepresentative values for dry materials, which are intended as design (not specification) values for materials in normal use. Insulation materials in actual service may have thermal values that vary from design values depending on their in-situ properties (e.g., density and moisture content). For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

^bThese temperatures are generally accepted as maximum. When operating temperature approaches these limits, follow the manufacturers' recommendations.

^cSome polyurethane foams are formed by means that produce a stable product (with respect to k), but most are blown with refrigerant and will change with time.

^dSee Table 4, footnote i.

^eSee Table 4, footnote j.

MECHANICAL AND INDUSTRIAL SYSTEMS

Thermal Transmission Data

Table 10 lists the thermal conductivities of various materials used as industrial insulations. These values are functions of the arithmetic mean of the temperatures of the inner and outer surfaces for each insulation.

Heat Loss from Pipes and Flat Surfaces

Tables 11A, 11B, and 12 give heat losses from bare steel pipes and flat surfaces and bare copper tubes. These tables were calculated using ASTM Standard C 680, Practice for Determination of Heat Gain or Loss and the Surface Temperature of Insulated Pipe and Equipment Systems by the Use of a Computer Program. User inputs for these programs include operating temperature, ambient temperature, pipe size, insulation type, number of insulation layers, and thickness for each layer. A program option allows the user to input a surface coefficient or surface emittance, surface orientation, and wind speed. The computer uses this information to calculate the heat flow and the surface temperature. The programs calculate the surface coefficients if the user has not already supplied them.

The equations used in ASTM C680 are:

$$h_{cv} = C \left(\frac{1}{d} \right)^{0.2} \left(\frac{1}{t_{avg}} \right)^{0.181} \Delta t^{0.266} \sqrt{1 + 1.277 (\text{Wind})} \quad (4)$$

where

h_{cv} = convection surface coefficient, Btu/h · ft² · °F
 d = diameter for cylinder, in. For flat surfaces and large cylinders ($d > 24$), use $d = 24$.

t_{avg} = average temperature of air film, °F
 Δt = surface to air temperature difference, °F

Wind = air speed, mph

- C = constant depending on shape and heat flow condition
 - = 1.016 for horizontal cylinders
 - = 1.235 for longer vertical cylinders
 - = 1.394 for vertical plates
 - = 1.79 for horizontal plates, warmer than air, facing upward
 - = 0.89 for horizontal plates, warmer than air, facing downward
 - = 0.89 for horizontal plates, cooler than air, facing upward
 - = 1.79 for horizontal plates, cooler than air, facing downward

$$h_{rad} = \frac{\epsilon \times 0.1713 \times 10^{-8} [(t_a + 459.6)^4 - (t_s + 459.6)^4]}{(t_a - t_s)} \quad (5)$$

where

h_{rad} = radiation surface coefficient, Btu/h · ft² · °F
 ϵ = surface emittance
 t_a = air temperature, °F
 t_s = surface temperature, °F

Table 11A Heat Loss from Bare Steel Pipe to Still Air at 80 °F^a, Btu/h · ft

Nominal Pipe Size ^b , in.	Pipe Inside Temperature, °F									
	180	280	380	480	580	680	780	880	980	1080
0.50	59.3	147.2	263.2	412.3	600.9	836.8	1128.6	1485.6	1918.0	2436.8
0.75	72.5	180.1	322.6	506.2	739.2	1031.2	1392.9	1836.0	2373.5	3018.8
1.00	88.8	220.8	396.1	622.7	910.9	1272.6	1721.2	2293.4	2939.4	3741.6
1.25	109.7	272.8	490.4	772.3	1131.7	1583.8	2145.6	2835.4	3673.4	4680.9
1.50	123.9	308.5	555.1	875.1	1283.8	1798.3	2438.2	3224.6	4180.5	5330.0
2.00	151.8	378.1	681.4	1076.3	1581.5	2218.9	3012.6	3989.2	5177.2	6606.8
2.50	180.5	450.0	811.9	1284.0	1888.8	2652.6	3604.3	4775.3	6199.5	7912.5
3.00	215.9	538.8	973.5	1541.8	2271.4	3194.0	4344.9	5762.2	7486.9	9562.3
3.50	243.9	609.0	1101.4	1746.1	2574.7	3623.6	4933.0	6546.4	8510.4	10874.3
4.00	271.6	678.6	1228.2	1948.7	2875.9	4050.5	5517.5	7326.0	9528.1	12178.9
4.50	299.2	747.7	1354.4	2150.9	3176.8	4477.7	6103.8	8109.5	10553.2	13496.2
5.00	329.8	824.7	1494.8	2375.4	3510.6	4950.7	6751.3	8972.5	11678.4	14936.3
6.00	387.1	968.7	1757.8	2796.8	4138.0	5841.4	7972.7	10603.1	13808.2	17667.6
7.00	440.5	1102.8	2003.0	3189.9	4723.9	6673.5	9114.2	12127.4	15799.4	20220.8
8.00	493.3	1235.7	2246.1	3580.0	5305.5	7500.0	10248.4	13642.2	17778.2	22758.0
9.00	545.9	1368.1	2488.8	3970.2	5888.7	8331.0	11392.1	15174.5	19787.1	25343.6
10.00	604.3	1514.8	2757.2	4400.7	6530.1	9241.1	12638.6	16835.1	21949.2	28104.9
11.00	656.0	1644.8	2995.5	4783.8	7102.1	10054.9	13756.2	18328.4	23900.3	30606.1
12.00	704.0	1762.3	3203.8	5104.9	7557.3	10661.8	14524.9	19256.7	24967.6	31766.8
14.00	771.0	1934.2	3525.9	5636.0	8373.9	11862.4	16235.5	21635.6	28212.3	36120.3
16.00	872.2	2189.0	3993.2	6387.4	9495.9	13458.0	18424.8	24556.6	32021.1	40990.7
18.00	972.5	2441.7	4456.7	7132.9	10609.4	15041.3	20596.7	27453.2	35795.6	45813.1
20.00	1072.1	2692.4	4916.8	7873.2	11715.1	16613.4	22752.5	30326.8	39537.6	50590.0
24.00	1269.3	3188.9	5828.3	9339.9	13905.5	19726.9	27019.7	36010.1	46930.3	60014.7

Table 11B Heat Loss from Flat Surfaces to Still Air at 80 °F, Btu/h · ft²

	Surface Inside Temperature, °F									
	180	280	380	480	580	680	780	880	980	1080
Vertical surface	212.2	533.1	973.3	1558.6	2321.2	3298.0	4530.1	6062.8	7945.5	10231.5
Horizontal surface										
Facing up	234.7	586.4	1061.1	1683.5	2484.9	3501.9	4775.4	6350.4	8276.3	10606.1
Facing down	183.6	465.3	861.4	1399.6	2112.8	3038.4	4217.8	5696.7	7524.5	9754.7

^aCalculations from ASTM C680-82; steel: $k = 314.4$ Btu · in/h · ft² · °F; $\epsilon = 0.94$.

^bLosses per square foot of pipe for pipes larger than 24 in. can be considered the same as losses per square foot for 24-in. pipe.

Example 7. Compute total annual heat loss from 165 ft of nominal 2-in. bare steel pipe in service 4000 h per year. The pipe is carrying steam at 10 psi and is exposed to an average air temperature of 80°F.

Solution: The pipe temperature is taken as the steam temperature, which is 239.4°F, obtained by interpolation from Steam Tables. By interpolation in Table 11A between 180°F and 280°F, heat loss from a 2-in. pipe is 285.3 Btu/h·ft. Total annual heat loss from the entire line is 285.3 Btu/h·ft × 165 ft × 4000 h = 188 million Btu.

In calculating heat flow, Equations (9) and (10) from Chapter 20 generally are used. For dimensions of standard pipe and fitting sizes, refer to the *Piping Handbook*. For insulation product dimensions, refer to ASTM *Standard C 585*, Recommended Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS) System, or to the insulation manufacturers' literature.

Examples 8 and 9 illustrate how Equations (9) and (10) from Chapter 20 can be used to determine heat loss from both flat and cylindrical surfaces. Figure 7 shows surface resistance as a function of heat transmission for both flat and cylindrical surfaces. The surface emittance is assumed to be 0.85 to 0.90 in still air at 80°F.

Example 8. Compute heat loss from a boiler wall if the interior insulation surface temperature is 1100°F and ambient still air temperature is 80°F. The wall is insulated with 4.5 in. of mineral fiber block and 0.5 in. of mineral fiber insulating and finishing cement.

Solution: Assume that the mean temperature of the mineral fiber block is 700°F, the mean temperature of the insulating cement is 200°F, and the surface resistance R_s is 0.60.

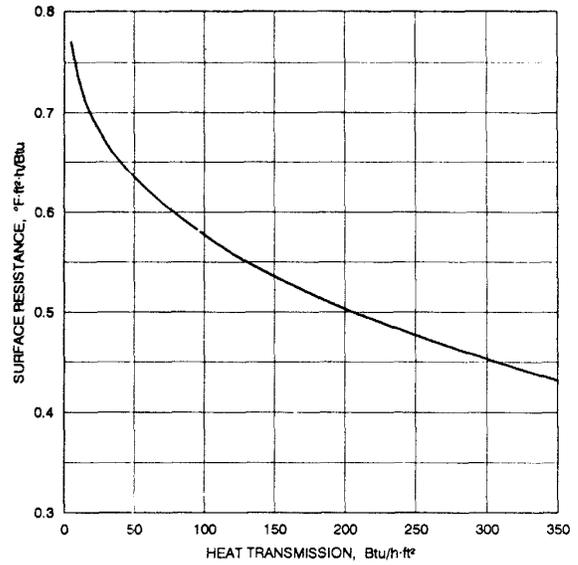


Fig. 7 Surface Resistance as Function of Heat Transmission for Flat Surfaces and Cylindrical Surfaces Greater than 24 Inches in Diameter

Table 12 Heat Loss from Bare Copper Tube to Still Air at 80°F^a, Btu/h·ft

Nominal Tube Size, in.	Tube Inside Temperature, °F							
	120	150	180	210	240	270	300	330
0.250	7.1	14.1	21.9	30.6	39.9	49.9	60.6	71.9
0.375	9.1	18.0	28.1	39.1	51.1	63.9	77.6	92.2
0.500	11.0	21.8	34.0	47.4	61.9	77.5	94.1	111.8
0.750	14.7	29.1	45.4	63.3	82.7	103.6	126.0	149.8
1.000	18.3	36.2	56.4	78.7	102.8	128.9	156.7	186.5
1.250	21.8	43.1	67.2	93.6	122.4	153.4	186.7	222.2
1.500	25.2	49.8	77.6	108.3	141.5	177.4	216.0	257.1
2.000	31.8	62.9	98.0	136.7	178.8	224.3	273.1	325.4
2.500	38.3	75.6	117.9	164.4	215.1	269.8	328.7	391.8
3.000	44.6	88.1	137.2	191.5	250.5	314.4	383.2	456.9
3.500	50.8	100.3	156.3	218.0	285.4	358.2	436.7	520.8
4.000	57.0	112.3	175.0	244.2	319.7	401.4	489.4	583.9
5.000	69.0	135.9	211.7	295.5	386.9	486.0	592.8	707.6
6.000	80.7	159.0	247.7	345.7	452.8	568.9	694.2	829.0
8.000	103.7	204.1	317.8	443.7	581.3	730.7	892.1	1066.0
10.000	126.1	247.9	386.1	539.1	706.5	888.4	1085.2	1297.4
12.000	148.0	290.9	453.0	632.5	829.2	1043.1	1274.6	1524.4
0.250	5.4	10.8	16.9	23.5	30.5	37.9	45.5	53.5
0.375	6.8	13.7	21.4	29.7	38.6	47.9	57.6	67.6
0.500	8.2	16.4	25.7	35.7	46.3	57.4	69.1	81.2
0.750	10.7	21.6	33.8	46.9	60.9	75.6	90.9	106.8
1.000	13.2	26.5	41.4	57.6	74.7	92.8	111.6	131.2
1.250	15.5	31.3	48.8	67.8	88.0	109.3	131.6	154.7
1.500	17.8	35.8	56.0	77.8	100.9	125.3	150.8	177.4
2.000	22.2	44.6	69.7	96.8	125.7	156.1	187.9	221.1
2.500	26.4	53.0	82.8	115.1	149.5	185.6	223.5	263.0
3.000	30.5	61.2	95.6	132.8	172.4	214.2	257.9	303.5
3.500	34.4	69.1	107.9	150.0	194.8	242.0	291.4	342.9
4.000	38.3	76.8	120.0	166.8	216.6	269.1	324.1	381.4
5.000	45.7	91.8	143.4	199.3	258.8	321.6	387.4	456.1
6.000	53.0	106.3	166.0	230.7	299.7	372.5	448.7	528.3
8.000	66.8	134.1	209.4	291.1	378.2	470.1	566.5	667.2
10.000	80.2	160.8	251.0	349.0	453.4	563.7	679.5	800.4
12.000	93.0	186.5	291.3	404.9	526.1	654.2	788.7	929.3

Dull $\epsilon = 0.44$

Bright $\epsilon = 0.08$

^aCalculations from ASTM C680-82; for copper: $k = 2784$ Btu·in/h·ft²·°F.

From Table 10, $k_1 = 0.62$ and $k_2 = 0.80$. Using Equation (9) from Chapter 20:

$$q_s = \frac{1100 - 80}{(4.5/0.62) + (0.5/0.80) + 0.60} = \frac{1020}{8.48} = 120.2 \text{ Btu/h} \cdot \text{ft}^2$$

As a check, from Figure 7, at $120.2 \text{ Btu/h} \cdot \text{ft}^2$, $R_s = 0.56$. The mean temperature of the mineral fiber block is:

$$4.5/0.62 = 7.26; 7.26/2 = 3.63$$

$$1100 - [(3.63/8.48)(1020)] = 1100 - 437 = 663^\circ\text{F}$$

and the mean temperature of the insulating cement is:

$$0.5/0.80 = 0.63; 0.63/2 = 0.31; 7.26 + 0.31 = 7.57$$

$$1100 - [(7.57/8.48)(1020)] = 1100 - 911 = 189^\circ\text{F}$$

From Table 10, at 663°F , $k_1 = 0.60$; at 189°F , $k_2 = 0.79$. Using these adjusted values to recalculate q_s :

$$q_s = \frac{1020}{(4.5/0.60) + (0.5/0.79) + 0.56} = \frac{1020}{8.69} = 117.4 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 7, at $117.4 \text{ Btu/h} \cdot \text{ft}^2$, $R_s = 0.56$. The mean temperature of the mineral fiber block is:

$$4.5/0.6 = 7.50; 7.50/2 = 3.75$$

$$1100 - [(3.75/8.69)(1020)] = 1100 - 440 = 660^\circ\text{F}$$

and the mean temperature of the insulating cement is:

$$0.5/0.79 = 0.63; 0.63/2 = 0.31; 7.50 + 0.31 = 7.81$$

$$1100 - [(7.81/8.69)(1020)] = 1100 - 917 = 183^\circ\text{F}$$

From Table 10, at 660°F , $k_1 = 0.60$; at 183°F , $k_2 = 0.79$.

Since R_s , k_1 , and k_2 do not change at these values, $q_s = 117.4 \text{ Btu/h} \cdot \text{ft}^2$.

Example 9. Compute heat loss per square foot of outer surface of insulation if pipe temperature is 1200°F and ambient still air temperature is 80°F . The pipe is nominal 6-in. steel pipe, insulated with a nominal 3-in. thick diatomaceous silica as the inner layer and a nominal 2-in. thick calcium silicate as the outer layer.

Solution: From Chapter 42 of the 1992 ASHRAE *Handbook—Equipment*, $r_o = 3.31$ in. A nominal 3-in. thick diatomaceous silica insulation to fit a nominal 6-in. steel pipe is 3.02 in. thick. A nominal 2-in. thick calcium silicate insulation to fit over the 3.02-in. diatomaceous silica is 2.08 in. thick. Therefore, $r_i = 6.33$ in. and $r_s = 8.41$ in.

Assume that the mean temperature of the diatomaceous silica is 600°F , the mean temperature of the calcium silicate is 250°F and the surface resistance R_s is 0.50. From Table 10, $k_1 = 0.66$; $k_2 = 0.42$. By Equation (10) from Chapter 20:

$$q_s = \frac{1200 - 80}{[8.41 \ln (6.33/3.31)/0.66] + [8.41 \ln (8.41/6.33)/0.40] + 0.50}$$

$$= \frac{1120}{(5.45/0.66) + (2.39/0.40) + 0.50} = 76.0 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 7, at $76.0 \text{ Btu/h} \cdot \text{ft}^2$, $R_s = 0.60$. The mean temperature of the diatomaceous silica is:

$$5.45/0.66 = 8.26; 8.26/2 = 4.13$$

$$1200 - [(4.13/14.83)(1120)] = 1200 - 312 = 888^\circ\text{F}$$

and the mean temperature of the calcium silicate is:

$$2.39/0.40 = 5.98; 5.98/2 = 2.99; 8.26 + 2.99 = 11.25$$

$$1200 - [(11.25/14.83)(1120)] = 1200 - 850 = 350^\circ\text{F}$$

From Table 10, $k_1 = 0.72$; $k_2 = 0.46$. Recalculating:

$$q_s = \frac{1120}{(5.45/0.72) + (2.39/0.46) + 0.60} = 83.8 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 7 at $83.8 \text{ Btu/h} \cdot \text{ft}^2$, $R_s = 0.59$. The mean temperature of the diatomaceous silica is:

$$5.45/0.72 = 7.57; 7.57/2 = 3.78$$

$$1200 - [(3.78/13.36)(1120)] = 1200 - 317 = 883^\circ\text{F}$$

and the mean temperature of the calcium silicate is:

$$2.39/0.46 = 5.20; 5.20/2 = 2.60; 7.57 + 2.60 = 10.17$$

$$1200 - [(10.17/13.36)(1120)] = 1200 - 853 = 347^\circ\text{F}$$

From Table 10, $k_1 = 0.72$; $k_2 = 0.46$. Recalculating:

$$q_s = \frac{1120}{(5.45/0.72) + (2.39/0.46) + 0.59} = 83.8 \text{ Btu/h} \cdot \text{ft}^2$$

Since R_s , k_1 , and k_2 do not change at $83.8 \text{ Btu/h} \cdot \text{ft}^2$, this is q_s . The heat flow per ft^2 of the inner surface of the insulation is:

$$q_o = q_s (r_s/r_o) = 83.8(8.41/3.31) = 213 \text{ Btu/h} \cdot \text{ft}^2$$

Because trial and error techniques are tedious, the computer programs previously described should be used to estimate heat flows per unit area of flat surfaces or per unit length of piping, and interface temperatures including surface temperatures.

Several methods can be used to determine the most effective thickness of insulation for piping and equipment. Table 13 shows the recommended insulation thicknesses for three different pipe and equipment insulations. Installed cost data can be developed using procedures described by the Federal Energy Administration (1976). Computer programs capable of calculating thickness information are available from several sources. Also, manufacturers of insulations offer computerized analysis programs for designers and owners to evaluate insulation requirements. For more information on determining economic insulation thickness, see Chapter 20.

Chapters 3 and 20 give guidance concerning process control, personnel protection, condensation control, and economics. For specific information on sizes of commercially available pipe insulation, see ASTM *Standard* C585 and consult with the Thermal Insulation Manufacturers Association (TIMA) and its member companies.

CALCULATING HEAT FLOW FOR BURIED PIPELINES

In calculating heat flow to or from buried pipelines, the thermal properties of the soil must be assumed. Table 7 gives the apparent thermal conductivity values of various soil types, and Figure 6 shows the typical trends of apparent soil thermal conductivity with moisture content for various soil types. Table 8 provides ranges of apparent thermal conductivity for various types of rock. Kernsten (1949) also discusses thermal properties of soils. Carslaw and Jaeger (1959) give methods for calculating the heat flow taking place between one or more buried cylinders and the surroundings.

Table 13 Recommended Thicknesses for Pipe and Equipment Insulation

Nominal Pipe Size, in.	MINERAL FIBER (Fiberglass and Rock Wool)										CALCIUM			
	Process Temperature, °F										150	250	350	
	150	250	350	450	550	650	750	850	950	1050				
½	Thickness	1	1½	2	2½	3	3½	4	4	4½	5½	1	1½	2
	Heat loss	8	16	24	33	43	54	66	84	100	114	13	24	34
	Surface temperature	72	75	76	78	79	81	82	86	87	87	75	78	80
1	Thickness	1	1½	2	2½	3½	4	4	4½	5	5½	1	2	2½
	Heat loss	11	21	30	41	49	61	79	96	114	135	16	26	38
	Surface temperature	73	76	78	80	79	81	84	86	88	89	76	76	79
1½	Thickness	1	2	2½	3	4	4	4	5½	5½	6	1½	2½	3
	Heat loss	14	22	33	45	54	73	94	103	128	152	17	29	42
	Surface temperature	73	74	77	79	79	82	86	84	88	90	73	75	78
2	Thickness	1½	2	3	3½	4	4	4	5½	6	6	1½	2½	3
	Heat loss	13	25	34	47	61	81	105	114	137	168	19	32	47
	Surface temperature	71	75	75	77	79	83	87	85	87	91	74	76	79
3	Thickness	1½	2½	3½	4	4	4½	4½	6	6½	7	2	3	3½
	Heat loss	16	28	39	54	75	94	122	133	154	184	21	37	54
	Surface temperature	72	74	75	77	81	83	87	86	87	90	73	75	78
4	Thickness	1½	3	4	4	4	5	5½	6	7	7½	2	3	4
	Heat loss	19	29	42	63	88	102	126	152	174	206	25	43	58
	Surface temperature	72	73	74	78	82	86	85	87	88	90	70	76	77
6	Thickness	2	3	4	4	4½	5	5½	6½	7½	8	2	3½	4
	Heat loss	21	38	54	81	104	130	159	181	208	246	33	51	75
	Surface temperature	71	74	75	79	82	84	87	88	89	91	74	75	79
8	Thickness	2	3½	4	4	5	5	5½	7	8	8½	2½	3½	4
	Heat loss	26	42	65	97	116	155	189	204	234	277	35	62	90
	Surface temperature	71	73	76	80	81	86	89	88	89	92	73	76	79
10	Thickness	2	3½	4	4	5	5½	5½	7½	8½	9	2½	4	4
	Heat loss	32	50	77	115	136	170	220	226	259	307	41	66	106
	Surface temperature	72	74	77	81	82	85	90	87	89	91	73	75	80
12	Thickness	2	3½	4	4	5	5½	5½	7½	8½	9½	2½	4	4
	Heat loss	36	57	87	131	154	192	249	253	290	331	47	75	121
	Surface temperature	72	74	77	82	82	86	91	88	89	91	73	76	81
14	Thickness	2	3½	4	4	5	5½	6½	7½	9	9½	2½	4	4
	Heat loss	40	61	94	141	165	206	236	271	297	352	51	81	130
	Surface temperature	72	74	77	82	83	86	87	89	89	91	73	76	81
16	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
	Heat loss	37	68	105	157	171	228	247	284	326	372	50	90	144
	Surface temperature	71	74	78	83	82	87	86	88	89	91	72	76	82
18	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
	Heat loss	41	75	115	173	187	250	270	310	354	404	55	99	159
	Surface temperature	71	74	78	83	83	87	87	88	90	91	73	76	82
20	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
	Heat loss	45	82	126	189	204	272	292	335	383	436	60	108	174
	Surface temperature	71	75	78	83	83	87	87	89	90	92	73	77	82
24	Thickness	2½	4	4	4	5½	6	7½	8	9	10	3	4	4
	Heat loss	53	86	147	221	237	295	320	386	439	498	71	127	203
	Surface temperature	71	74	78	83	83	86	86	89	91	93	73	77	82
30	Thickness	2½	4	4	4	5½	6½	7½	8½	10	10	3	4	4
	Heat loss	65	105	179	268	286	332	383	439	481	591	86	154	247
	Surface temperature	71	74	79	84	84	85	87	89	89	94	73	77	83
36	Thickness	2½	4	4	4	5½	7	8	9	10	10	2½	4	4
	Heat loss	77	123	211	316	335	364	422	486	556	683	119	181	291
	Surface temperature	71	74	79	84	84	84	86	88	90	94	74	77	83
Flat	Thickness	2	3½	4	4½	5½	8½	9½	10	10	10	2½	3½	4
	Heat loss	10	14	20	27	31	27	31	38	47	58	12	20	28
	Surface temperature	72	74	77	80	82	80	82	85	89	93	73	77	81

Consult manufacturer's literature for product temperature limitations. Table is based on typical operating conditions, e.g., 65 °F ambient temperature and 7.5 mph wind speed, and may not represent actual conditions of use. Units for thickness, heat loss, and surface temperature are in inches, Btu/h · ft (Btu/h · ft² for flat surfaces), and °F, respectively.

Table 13 Recommended Thicknesses for Pipe and Equipment Insulation (Concluded)

SILICATE							CELLULAR GLASS						
Process Temperature, °F							Process Temperature, °F						
450	550	650	750	850	950	1050	150	250	350	450	550	650	750
2½	3	3½	4	4	4	4	1½	1½	2	2½	3	3½	4
42	53	63	75	90	108	128	9	23	34	48	62	78	92
81	82	83	84	87	91	94	70	76	78	82	83	85	84
3	3½	4	4	4	4	4	1½	2	2½	3	3½	4	4
49	60	72	89	109	130	154	12	25	38	52	68	86	112
80	82	83	86	90	94	98	71	75	77	79	81	83	88
3½	4	4	4	4	5	5	1½	2½	3	4	4	4	4
54	68	86	106	128	139	164	15	28	44	56	79	105	137
80	81	85	88	92	91	94	72	75	77	78	82	87	92
3½	4	4½	5	5½	6	6	1½	2½	3	4	4	4	4½
61	75	90	106	123	142	167	17	31	47	61	84	113	140
81	82	84	85	87	88	91	72	74	77	78	82	86	89
4	4½	5	5½	6	6	6	1½	3	3½	4	4	4½	5
71	87	105	123	143	71	202	22	35	54	75	105	132	161
80	82	84	85	87	90	94	73	74	77	79	84	86	89
4	4½	5	5½	6	6½	7	2	3	4	4	4	4½	5
82	101	121	142	164	187	213	22	41	59	87	122	150	185
81	83	85	87	89	90	92	71	74	76	80	85	87	90
4	4½	5	5½	6	7	8	2	3½	4	4	4½	5½	6
105	129	153	178	205	224	245	30	48	74	111	144	171	212
83	85	87	89	91	91	91	72	74	77	82	85	86	89
4½	5	5	6	7	8	8½	2½	3½	4	4	5	5½	6½
117	144	183	200	220	243	277	30	58	90	134	161	203	238
82	85	89	89	89	90	92	71	74	78	83	84	87	89
4	5	5½	6	7½	8½	9	2½	4	4	4	5½	5½	7
149	168	200	233	243	269	306	37	63	106	159	178	238	264
85	86	88	90	89	89	91	71	74	79	84	84	87	88
4	5	5½	7	8	8½	9½	2½	4	4	4	5½	5½	7½
170	191	266	236	262	300	330	42	71	121	181	201	269	284
86	86	89	88	88	90	91	71	74	79	85	84	90	88
4	5	5½	7	8	9	9½	2½	4	4	4	5½	5½	8
183	205	242	252	262	308	352	47	79	134	199	219	293	293
86	87	89	88	88	89	91	72	74	80	85	85	91	87
4	5½	6½	7½	8	9	10	2½	4	4	4	5½	5½	8
204	211	237	265	307	338	372	53	88	149	222	242	325	322
87	85	86	87	89	90	91	72	75	80	86	86	91	88
4	5½	6½	7½	8½	9	10	2½	4	4	4	5½	5½	8
225	232	259	289	320	367	403	59	96	164	245	266	356	351
87	86	87	87	88	90	91	72	75	80	86	86	92	88
4	5½	6½	7½	8½	9½	10	2½	4	4	4½	5½	5½	8
245	252	281	312	346	381	435	64	105	179	243	289	387	379
87	86	87	88	89	90	92	72	75	81	84	86	92	88
4	5½	6½	7½	8½	9½	10	2½	4	4	5	5½	5½	8
287	293	325	360	397	437	497	76	123	209	260	336	449	436
88	87	88	88	89	90	93	72	75	81	83	87	93	89
4	5½	7	8	9	10	10	2½	4	4	5½	5½	5½	8
349	353	368	409	452	498	589	93	150	254	290	405	542	521
88	87	87	88	89	90	94	72	75	81	82	87	93	90
4	6½	7½	8	9	10	10	2½	4	4	5½	5½	5½	8
410	359	406	475	524	576	681	110	176	229	340	474	635	606
89	84	86	88	89	91	94	73	76	81	82	88	94	90
5½	6½	7½	8½	9½	10	10	2½	4	4	5½	5½	7½	8½
29	33	36	39	43	49	58	11	17	29	31	44	43	50
81	83	84	85	87	89	93	73	76	83	84	90	90	93

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Table B-2: Framed Wall Assembly U-values

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-Value	Metal Wall U-Value
2x4 @ 16" O.C.	11 (compressed)	0	0.098	0.202
		4	0.068	0.112
		5	0.064	0.101
		7	0.056	0.084
		8.7	0.051	0.073
	13	0	0.088	0.195
		4	0.063	0.109
		5	0.059	0.099
		7	0.052	0.082
		8.7	0.048	0.072
	15	0	0.081	0.189
		4	0.059	0.108
5		0.055	0.097	
7		0.049	0.077	
8.7		0.045	0.071	
2x4 @ 24" O.C.	11	0	0.094	0.173
		4	0.066	0.102
		5	0.062	0.093
		7	0.055	0.078
		8.7	0.050	0.069
	13	0	0.085	0.165
		4	0.061	0.099
		5	0.057	0.090
		7	0.051	0.077
		8.7	0.047	0.068
	15	0	0.077	0.158
		4	0.056	0.097
5		0.053	0.088	
7		0.047	0.071	
8.7		0.044	0.067	

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-Value	Metal Wall U-Value
2x6 @ 16" O.C.	19 (compressed)	0	0.065	0.120
		4	0.058	0.098
		5	0.048	0.089
		7	0.043	0.075
		8.7	0.040	0.067
	21	0	0.059	0.157
		4	0.046	0.096
		5	0.044	0.088
		7	0.041	0.075
		8.7	0.037	0.066
	22 (compressed)	0	0.062	0.158
		4	0.048	0.097
5		0.045	0.088	
7		0.041	0.075	
8.7		0.038	0.067	
2x6 @ 24" O.C.	19 (compressed)	0	0.062	0.135
		4	0.048	0.088
		5	0.045	0.081
		7	0.042	0.070
		8.7	0.039	0.062
	21	0	0.056	0.130
		4	0.044	0.086
		5	0.042	0.079
		7	0.039	0.068
		8.7	0.036	0.061
	22 (compressed)	0	0.058	0.132
		4	0.046	0.086
5		0.043	0.079	
7		0.040	0.068	
8.7		0.037	0.061	

Table B-2 (cont'd): Framed Wall Assembly U-values

Framing Type and Spacing	Framing	Insulated	Wood Wall	Metal Wall
	Cavity	Sheathing	U-Value	U-Value
	R-Value	R-Value		
2x8 @ 16" O.C.	19	0	0.059	0.145
		4	0.047	0.092
		5	0.044	0.084
		7	0.041	0.072
		8.7	0.038	0.064
	22	0	0.054	0.140
		4	0.043	0.090
		5	0.041	0.082
		7	0.038	0.071
		8.7	0.035	0.063
	25	0	0.050	0.136
		4	0.040	0.088
		5	0.038	0.081
		7	0.035	0.070
		8.7	0.033	0.062
	30 (compressed)	0	0.048	0.135
4		0.039	0.088	
5		0.037	0.081	
7		0.035	0.070	
8.7		0.032	0.062	
2x8 @ 24" O.C.	19	0	0.056	0.122
		4	0.045	0.082
		5	0.043	0.076
		7	0.040	0.066
		8.7	0.037	0.059
	22	0	0.051	0.117
		4	0.041	0.080
		5	0.040	0.074
		7	0.036	0.064
		8.7	0.034	0.058
	25	0	0.047	0.113
		4	0.038	0.078
		5	0.037	0.072
		7	0.034	0.063
		8.7	0.032	0.057
	30 (compressed)	0	0.046	0.112
		4	0.037	0.077
		5	0.036	0.072
		7	0.034	0.063
		8.7	0.031	0.057

Framing Type and Spacing	Framing	Insulated	Wood Wall	Metal Wall
	Cavity	Sheathing	U-Value	U-Value
	R-Value	R-Value		
2x10 @ 16" O.C.	30	0	0.041	0.120
		4	0.035	0.081
		5	0.033	0.075
		7	0.031	0.065
		8.7	0.029	0.059
	38 (compressed)	0	0.040	0.119
		4	0.033	0.080
		5	0.032	0.074
		7	0.030	0.065
		8.7	0.028	0.058
2x10 @ 24" O.C.	30 (compressed)	0	0.039	0.099
		4	0.033	0.071
		5	0.032	0.066
		7	0.030	0.058
		8.7	0.028	0.053
	38	0	0.038	0.097
		4	0.032	0.070
		5	0.031	0.066
		7	0.029	0.058
		8.7	0.027	0.053

Table B-2a: Solar Heat Gain Coefficients Used for Exterior Shading¹

Exterior Shading Device	SHGC
Standard Bug Screens	0.76
Exterior Sunscreens with weave 53*16/inch	0.30
Louvered Sunscreens with louvers as wide as openings	0.27
Low Sun Angle (LSA) Louvered Sunscreens	0.13
Roll-down Awning	0.13
Roll Down Blinds or Slats	0.13
None (for skylights only)	1.00
1) Exterior operable awnings (canvas, plastic or metal), except those that roll vertically down and cover the entire window, should be treated as overhangs for purposes of compliance with the Standards.	

Table B-3: Metal Framing Factor

METAL FRAMING FACTORS			
Stud Spacing	Stud Depth	Insulation R-Value	Framing Factor
16" o.c.	4"	R-7	0.522
		R-11	0.403
		R-13	0.362
		R-15	0.328
	6"	R-19	0.325
		R-21	0.300
		R-22	0.287
		R-25	0.263
24" o.c.	4"	R-7	0.577
		R-11	0.458
		R-13	0.415
		R-15	0.379
	6"	R-19	0.375
		R-21	0.348
		R-22	0.335
		R-25	0.308
R-value calculation for Exterior Wall Assemblies with Metal Studs, July, 19, 1990, Staff Draft Docket 90-CON-1.			
*Correction to metal framing factors applies to the entire assembly including: interior air films, interior surfaces, cavity/insulation, exterior surfaces, and exterior air films.			

Table B-4: Properties of Hollow Unit Masonry Walls

Type			Core Treatment		
			Solid Grout	Partly Grouted with UngROUTED Cells	
				Empty	Insulated
12"	LW CMU	U	0.51	0.43	0.30
		Rw	2.0	2.3	3.3
		HC	23	14.8	14.8
	MW CMU	U	0.54	0.46	0.33
		Rw	1.9	2.2	3.0
		HC	23.9	15.6	15.6
	NW CMU	U	0.57	0.49	0.36
		Rw	1.8	2.0	2.8
		HC	24.8	16.5	16.5
10"	LW CMU	U	0.55	0.46	0.34
		Rw	1.8	2.2	2.9
		HC	18.9	12.6	12.6
	MW CMU	U	0.59	0.49	0.37
		Rw	1.7	2.1	2.7
		HC	19.7	13.4	13.4
	NW CMU	U	0.62	0.52	0.41
		Rw	1.6	1.9	2.4
		HC	20.5	14.2	14.2
8"	LW CMU	U	0.62	0.50	0.37
		Rw	1.6	2.0	2.7
		HC	15.1	9.9	9.9
	MW CMU	U	0.65	0.53	0.41
		Rw	1.5	1.9	2.4
		HC	15.7	10.5	10.5
	NW CMU	U	0.69	0.56	0.44
		Rw	1.4	1.8	2.3
		HC	16.3	11.1	11.1
	Clay Unit	U	0.57	0.47	0.39
		Rw	1.8	2.1	2.6
		HC	15.1	11.4	11.4
6"	LW CMU	U	0.68	0.54	0.44
		Rw	1.5	1.9	2.3
		HC	10.9	7.9	7.9
	MW CMU	U	0.72	0.58	0.48
		Rw	1.4	1.7	2.1
		HC	11.4	8.4	8.4
	NW CMU	U	0.76	0.61	0.52
		Rw	1.3	1.6	1.9
		HC	11.9	8.9	8.9
	Clay Unit	U	0.65	0.52	0.45
		Rw	1.5	1.9	2.2
		HC	11.1	8.6	8.6

Notes:

LW CMU is a Light Weight Concrete Masonry Unit per ASTM C 90, Calculated at 105 PCF density
 MW CMU is a Medium Weight Concrete Masonry Unit per ASTM C 90, Calculated at 115 PCF density
 NW CMU is a Normal Weight Concrete Masonry Unit per ASTM C 90, Calculated at 125 PCF density
 Clay Unit is a Hollow Clay Unit per ASTM C 652, Calculated at 130 PCF density

Values include air films on inner and outer surfaces.

Calculations based on Energy Calculations and Data, CMAACN, 1986

Grouted Cells at 32" X 48" in Partly Grouted Walls

Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada

Table B-5: Properties of Solid Unit Masonry and Solid Concrete Walls

Type		Layer Thickness, inches									
		3	4	5	6	7	8	9	10	11	12
LW CMU	U	na	0.71	0.64	na						
	Rw	na	1.4	1.6	na						
	HC	na	7.00	8.75	na						
MW CMU	U	na	0.76	0.70	na						
	Rw	na	1.3	1.4	na						
	HC	na	7.67	9.58	na						
NW CMU	U	0.89	0.82	0.76	na						
	Rw	1.1	1.2	1.3	na						
	HC	6.25	8.33	10.42	na						
Clay Brick	U	0.80	0.72	0.66	na						
	Rw	1.3	1.4	1.5	na						
	HC	6.30	8.40	10.43	na						
Concrete	U	0.96	0.91	0.86	0.82	0.78	0.74	0.71	0.68	0.65	0.63
	Rw	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6
	HC	7.20	9.60	12.00	14.40	16.80	19.20	21.60	24.00	26.40	28.80

Notes:

LW CMU is a Light Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 105 PCF density
 MW CMU is a Medium Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 115 PCF density
 NW CMU is a Normal Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 125 PCF density
 Clay Brick is a Clay Unit per ASTM C 62, Calculated at 130 PCF density
 Concrete is structural poured or precast concrete, Calculated at 144 PCF density
 Calculations based on Energy Calculations and Data, CMAACN, 1986
 Values include air films on inner and outer surfaces.

Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada

Table B-6: Effective R-values for Interior Insulation Layers on Structural Mass Walls

Type Actual Thick	Frame	Furring space R-value without framing effects																					
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Any	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
0.5"	Wood	1.3	1.3	1.9	2.4	2.7	na	na	na	na	na	na	na	na	na	na	na						
	Metal	0.9	0.9	1.1	1.1	1.2	na	na	na	na	na	na	na	na	na	na	na						
0.75"	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1.0"	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	na	na	na	na	na	na	na	na	na	na	na	na	na
1.5"	Wood	1.3	1.5	2.4	3.1	3.8	4.4	4.9	5.4	5.8	6.2	6.5	6.8	7.1	na								
	Metal	1.1	1.2	1.6	1.9	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.6	2.7	na								
2"	Wood	1.4	1.5	2.5	3.3	4.0	4.7	5.3	5.9	6.4	6.9	7.3	7.7	8.1	8.4	8.7	9.0	9.3	na	na	na	na	na
	Metal	1.1	1.2	1.7	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.3	3.4	3.4	na	na	na	na	na
2.5"	Wood	1.4	1.5	2.5	3.4	4.2	4.9	5.6	6.3	6.8	7.4	7.9	8.4	8.8	9.2	9.6	10.0	10.3	10.6	10.9	11.2	11.5	na
	Metal	1.2	1.3	1.8	2.3	2.6	2.8	3.0	3.2	3.3	3.5	3.6	3.6	3.7	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.1	na
3"	Wood	1.4	1.5	2.5	3.5	4.3	5.1	5.8	6.5	7.2	7.8	8.3	8.9	9.4	9.9	10.3	10.7	11.1	11.5	11.9	12.2	12.5	12.9
	Metal	1.2	1.3	1.9	2.4	2.8	3.1	3.3	3.5	3.7	3.8	4.0	4.1	4.2	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.7	4.8
3.5"	Wood	1.4	1.5	2.6	3.5	4.4	5.2	6.0	6.7	7.4	8.1	8.7	9.3	9.8	10.4	10.9	11.3	11.8	12.2	12.6	13.0	13.4	13.8
	Metal	1.2	1.3	2.0	2.5	2.9	3.2	3.5	3.8	4.0	4.2	4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.1	5.2	5.2	5.3
4"	Wood	1.4	1.6	2.6	3.6	4.5	5.3	6.1	6.9	7.6	8.3	9.0	9.6	10.2	10.8	11.3	11.9	12.4	12.8	13.3	13.7	14.2	14.6
	Metal	1.2	1.3	2.0	2.6	3.0	3.4	3.7	4.0	4.2	4.5	4.6	4.8	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.8
4.5"	Wood	1.4	1.6	2.6	3.6	4.5	5.4	6.2	7.1	7.8	8.5	9.2	9.9	10.5	11.2	11.7	12.3	12.8	13.3	13.8	14.3	14.8	15.2
	Metal	1.2	1.3	2.1	2.6	3.1	3.5	3.9	4.2	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3
5"	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.3	7.2	8	8.7	9.4	10.1	10.8	11.5	12.1	12.7	13.2	13.8	14.3	14.8	15.3	15.8
	Metal	1.2	1.4	2.1	2.7	3.2	3.7	4.1	4.4	4.7	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.2	6.3	6.5	6.6	6.7	6.8
5.5"	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.4	7.3	8.1	8.9	9.6	10.3	11.0	11.7	12.4	13.0	13.6	14.2	14.7	15.3	15.8	16.3
	Metal	1.3	1.4	2.1	2.8	3.3	3.8	4.2	4.6	4.9	5.2	5.4	5.7	5.9	6.1	6.3	6.4	6.6	6.7	6.8	7.0	7.1	7.2

All furring thickness values given are actual dimensions

All values include .5" gypbd. on the inner surface, interior surface resistances not included

24" OC Furring

24 Gage, Z-type Metal Furring

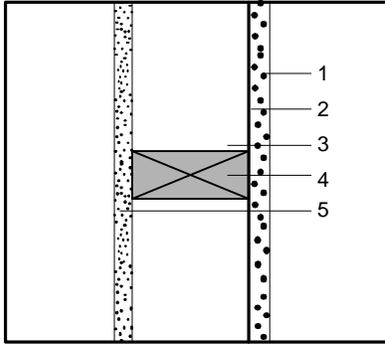
Douglas-Fir Larch Wood Furring, density = 34.9 lb/cu.ft.

Insulation assumed to fill the furring space

[Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada]

Table B-7: Framed Wall/Floor/Ceiling Assembly U-Values

Reference Name: W.0.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 4

Framing Spacing:

16 "o.c."

Framing Percentage:
(check one)

Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling: 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

	Outside Surface Air Film
1.	<u>0.875 in stucco</u>
2.	<u>Building paper (felt)</u>
3.	<u>3.5" & greater air space; heat sideways</u>
4.	<u>2x4 in fir framing</u>
5.	<u>0.50 in gypsum or plaster board</u>
6.	
7.	
	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
<u>0.170</u>	<u>0.170</u>
<u>0.175</u>	<u>0.175</u>
<u>0.060</u>	<u>0.600</u>
<u>0.850</u>	<u>-----</u>
<u>-----</u>	<u>3.465</u>
<u>0.450</u>	<u>0.450</u>
<u>-----</u>	<u>-----</u>
<u>0.680</u>	<u>0.680</u>
<u>2.385</u>	<u>5.000</u>
R_c	R_f

Framing Adjustment Calculation:

$$\left[\frac{1}{2.385} \times \left(\frac{1-15/100}{1-15/100} \right) \right] + \left[\frac{1}{5.000} \times \left(\frac{15/100}{15/100} \right) \right] = \frac{1}{0.385}$$

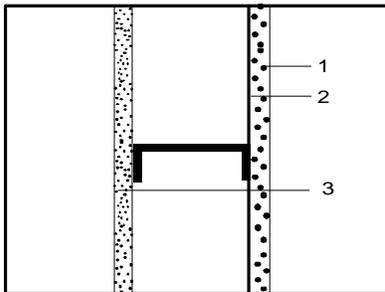
1 ÷ Total U-Value

0.385
Total U-Value

2.591

Total R-Value

Reference Name: W.0.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c."

Framing Size:

Actual Depth 3.625

Actual Width 1.625

Cavity Insulation:

R-value 0.850

Knock-out (%) 15.00

Web Thickness 0.060

Insulation Tape R-value:

Interior Flange 0.0

Exterior Flange 0.0

List of Construction Components

	Outside Surface Air Film
1.	<u>0.875 in stucco</u>
2.	<u>Building paper (felt)</u>
3.	<u>0.50 in gypsum or plaster board</u>
4.	
5.	
6.	
7.	
	Inside Surface Air Film

R-Value

0.170

0.175

0.060

0.450

0.680

Calculation:

From EZFRAME

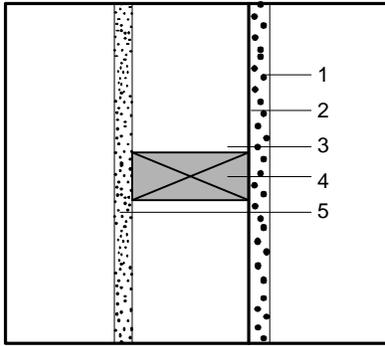
0.449
Total U-Value

$$\frac{1}{0.449} = 2.23$$

1 ÷ Total U-Value

Total R-Value

Reference Name: W.0.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 4

Framing Spacing:

24 "o.c."

Framing Percentage:
(check one)

- Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

1.	Outside Surface Air Film
	0.875 in stucco
2.	Building paper (felt)
3.	3.5" & greater air space; heat sideways
4.	2x4 in fir framing
5.	0.50 in gypsum or plaster board
6.	
7.	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.600
0.850	-----
-----	3.465
0.450	0.450
-----	-----
0.680	0.680
2.385	5.000
R _c	R _f

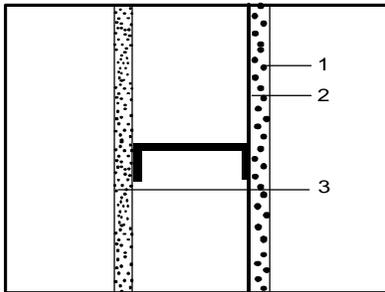
Framing Adjustment Calculation:

$$\left[\frac{1/2.385}{1+R_c} \times \left(\frac{1-12/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/5.000}{1+R_f} \times \left(\frac{12/100}{Fr.\% \div 100} \right) \right] = \boxed{0.393}$$

Total U-Value

$$\frac{1/0.393}{1+Total\ U-Value} = \frac{2.546}{Total\ R-Value}$$

Reference Name: W.0.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

24 "o.c."

Framing Size:

Actual Depth 3.625
Actual Width 1.625

Cavity Insulation:

R-value 0.850

Insulation Tape R-value:

Knock-out (%) 15.00
Web Thickness 0.060
Interior Flange 0.0
Exterior Flange 0.0

List of Construction Components

1.	Outside Surface Air Film
	0.875 in stucco
2.	Building paper (felt)
3.	0.50 in gypsum or plaster board
4.	
5.	
6.	
7.	Inside Surface Air Film

R-Value

0.170
0.175
0.060
0.450

0.680

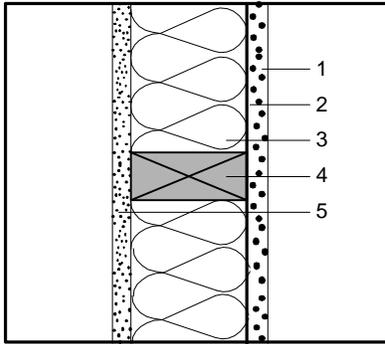
Calculation:

From EZFRAME = $\boxed{0.443}$

Total U-Value

$$\frac{1/0.443}{1+Total\ U-Value} = \frac{2.260}{Total\ R-Value}$$

Reference Name: W.7.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 × 4
16 "o.c."
Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

1.	Outside Surface Air Film
	0.875 in stucco
2.	Building paper (felt)
3.	R-7 fiberglass insulation
4.	2x4 in fir framing
5.	0.50 in gypsum or plaster board
6.	
7.	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.600
7.000	-----
-----	3.465
0.450	0.450
-----	-----
0.680	0.680
8.535	5.000
R _c	R _f

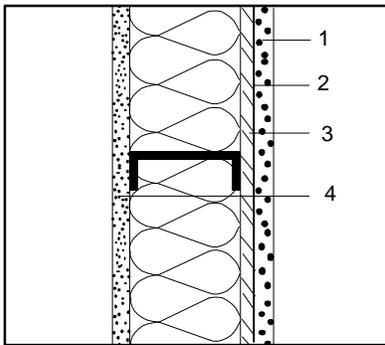
Framing Adjustment Calculation:

$$\left[\frac{1/8.535}{1+R_c} \times \left(\frac{1-15/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/5.00}{1+R_f} \times \left(\frac{15/100}{Fr.\% \div 100} \right) \right] = \boxed{0.130}$$

Total U-Value

$$\frac{1/0.130}{1+Total\ U-Value} = \frac{7.69}{Total\ R-Value}$$

Reference Name: W.7.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
16 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 7.00
Knock-out (%) 15.00
Web Thickness 0.0600
Interior Flange 0.0
Exterior Flange 0.0

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

1.	Outside Surface Air Film
	0.875 in stucco
2.	Building paper (felt)
3.	0.50 in polyisocyanurate
4.	0.50 in gypsum or plaster board
5.	
6.	
7.	Inside Surface Air Film

R-Value

0.170
0.175
0.060
3.500
0.450

0.680

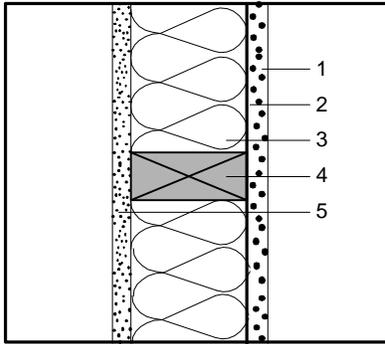
Calculation:

From EZFRAME = $\boxed{0.125}$

Total U-Value

$$\frac{1/0.125}{1+Total\ U-Value} = \frac{7.990}{Total\ R-Value}$$

Reference Name: W.7.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 4
24 "o.c."

Framing Spacing:

Framing Percentage:
(check one)

Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling: 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

1.	Outside Surface Air Film
	0.875 in stucco
2.	Building paper (felt)
3.	R-7 Fiberglass Insulation
4.	2x4 in fir framing
5.	0.50 in gypsum or plaster board
6.	
7.	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.600
7.000	-----
-----	3.465
0.450	0.450
-----	-----
0.680	0.680
8.535	5.000
R _c	R _f

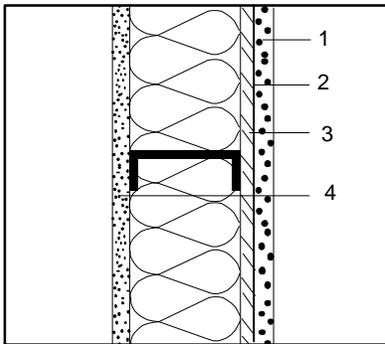
Framing Adjustment Calculation:

$$\left[\frac{1/8.535}{1+R_c} \times \frac{(1-15/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/5.00}{1+R_f} \times \frac{(15/100)}{Fr.\% \div 100} \right] = \frac{1/0.127}{1+Total\ U-Value}$$

0.127
Total U-Value

7.874
Total R-Value

Reference Name: W.7.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

24 "o.c."

Framing Size:

Actual Depth 3.625
Actual Width 1.625

Cavity Insulation:

R-value 7.00
Knock-out (%) 15.00

Insulation Tape R-value:

Web Thickness 0.0600
Interior Flange 0.0
Exterior Flange 0.0

List of Construction Components

1.	Outside Surface Air Film
	0.875 in stucco
2.	Building paper (felt)
3.	0.50 in polyisocyanurate
4.	0.50 in gypsum or plaster board
5.	
6.	
7.	Inside Surface Air Film

R-Value

0.170
0.175
0.060
3.500
0.450

0.680

Calculation:

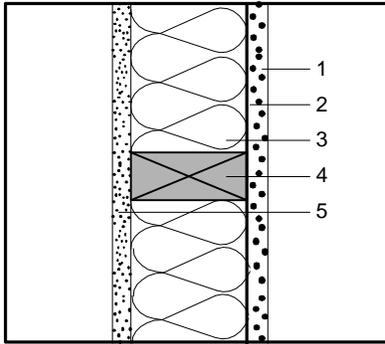
From EZFRAME

0.117
Total U-Value

$$\frac{1/0.117}{1+Total\ U-Value}$$

8.530
Total R-Value

Reference Name: W.11.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 4

Framing Spacing:

16 "o.c."

Framing Percentage:
(check one)

Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

	Outside Surface Air Film
1.	0.875 in stucco
2.	Building paper (felt)
3.	R-11 fiberglass insulation
4.	2x4 in fir framing
5.	0.50 in gypsum or plaster board
6.	
7.	
	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.060
11.000	-----
-----	3.465
0.450	0.450
-----	-----
-----	-----
0.680	0.680
12.535	5.00
R _c	R _f

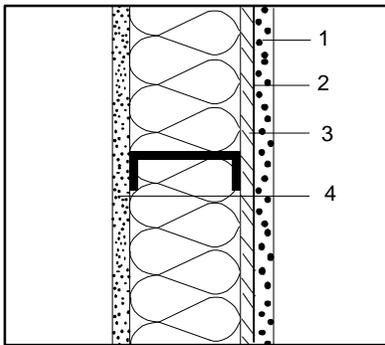
Framing Adjustment Calculation:

$$\left[\frac{1/12.535}{1+R_c} \times \left(\frac{1-15/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/5.00}{1+R_f} \times \left(\frac{15/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.098}{1+\text{Total U-Value}} =$$

0.098
Total U-Value
10.204
Total R-Value

Reference Name: W.11.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c."

Framing Size:

Actual Depth 3.625
Actual Width 1.625

Cavity Insulation:

R-value 11.00
Knock-out (%) 15.00

Insulation Tape R-value:

Web Thickness 0.060
Interior Flange 0.0
Exterior Flange 0.0

List of Construction Components

	Outside Surface Air Film
1.	0.875 in stucco
2.	Building paper (felt)
3.	0.75 in polyisocyanurate
4.	0.50 in gypsum or plaster board
5.	
6.	
7.	
	Inside Surface Air Film

R-Value

0.170
0.175
0.060
5.250
0.450

0.680

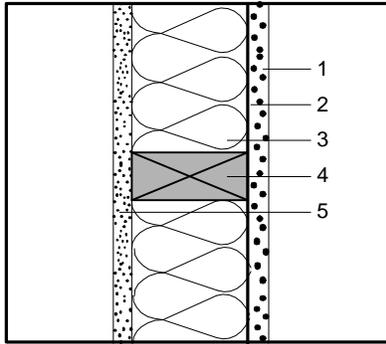
Calculation:

From EZFRAME

$$\frac{1/0.096}{1+\text{Total U-Value}} =$$

0.096
Total U-Value
10.360
Total R-Value

Reference Name: W.11.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 × 4
24 "o.c."
Wall: _____ 15% (16"o.c.)
 12% (24"o.c.)
 _____ 9% (48"o.c.)
Floor/Ceiling _____ 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

1.	Outside Surface Air Film
2.	0.875 in stucco
3.	Building paper (felt)
4.	R-11 fiberglass insulation
5.	2x4 in fir framing
6.	0.50 in gypsum or plaster board
7.	Inside Surface Air Film

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.600
11.00	-----
-----	3.465
0.450	0.450
0.680	0.680
12.535	5.00
R _c	R _f

Total Unadjusted R-Values:

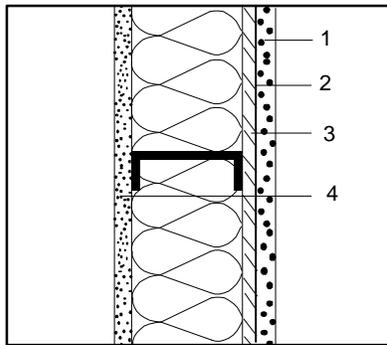
Framing Adjustment Calculation:

$$\left[\frac{1/12.535}{1+R^c} \times \left(\frac{1-12/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/5.00}{1+R^f} \times \left(\frac{12/100}{Fr.\% \div 100} \right) \right] = \boxed{0.094}$$

Total U-Value

$$\frac{1/0.094}{1+Total\ U-Value} = \frac{10.638}{Total\ R-Value}$$

Reference Name: W.11.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
24 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 11.000
Knock-out (%) 15.000
Web Thickness 0.060
Interior Flange 0.0
Exterior Flange 0.0

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

1.	Outside Surface Air Film
2.	0.875 in stucco
3.	Building paper (felt)
4.	0.75 in polyisocyanurate
5.	0.50 in gypsum or plaster board
6.	Inside Surface Air Film

R-Value	
0.170	
0.175	
0.060	
5.250	
0.450	
0.680	

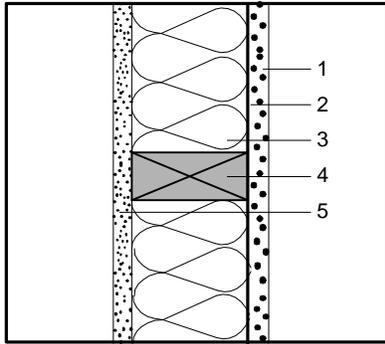
Calculation:

From EZFRAME = $\boxed{0.090}$

Total U-Value

$$\frac{1/0.090}{1+Total\ U-Value} = \frac{11.140}{Total\ R-Value}$$

Reference Name: W.13.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 × 4
16 "o.c."
Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

1.	0.875 in stucco
2.	Building paper (felt)
3.	R-13 fiberglass insulation
4.	2x4 in fir framing
5.	0.50 in gypsum or plaster board
6.	
7.	
	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.600
13.00	-----
-----	3.465
0.450	0.450
-----	-----
0.680	0.680
14.535	5.00
R _c	R _f

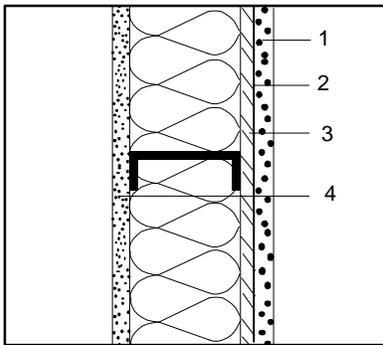
Framing Adjustment Calculation:

$$\left[\frac{1/14.535}{1+R^c} \times \left(\frac{1-15/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/5.00}{1+R^f} \times \left(\frac{15/100}{Fr.\% \div 100} \right) \right] = \boxed{0.088}$$

Total U-Value

$$\frac{1/0.088}{1+\text{Total U-Value}} = \frac{11.364}{\text{Total R-Value}}$$

Reference Name: W.13.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
16 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 13.000
Knock-out (%) 15.00
Web Thickness 0.060
Interior Flange 0.0
Exterior Flange 0.0

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

1.	0.875 in stucco
2.	Building paper (felt)
3.	1.00 in Polyisocyanurate
4.	0.50 in gypsum or plaster board
5.	
6.	
7.	
	Inside Surface Air Film

R-Value

0.170
0.175
0.060
7.000
0.450

0.680

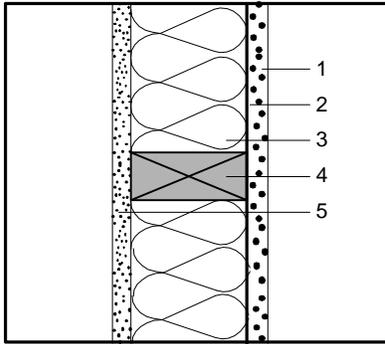
Calculation:

From EZFRAME = $\boxed{0.081}$

Total U-Value

$$\frac{1/0.081}{1+\text{Total U-Value}} = \frac{12.330}{\text{Total R-Value}}$$

Reference Name: W.13.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 × 4
24 "o.c."
Wall: _____ 15% (16"o.c.)
 12% (24"o.c.)
 _____ 9% (48"o.c.)
Floor/Ceiling _____ 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
NA _____

Wall Weight / sf:
(Packages only)

List of Construction Components

1.	Outside Surface Air Film
	0.875 in stucco
2.	Building paper (felt)
3.	R-13 fiberglass insulation
4.	2x4 in fir framing
5.	0.50 in gypsum or plaster board
6.	
7.	Inside Surface Air Film

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.600
13.000	-----
-----	3.465
0.450	0.450
-----	-----
0.680	0.680
14.535	5.00
R _c	R _f

Total Unadjusted R-Values:

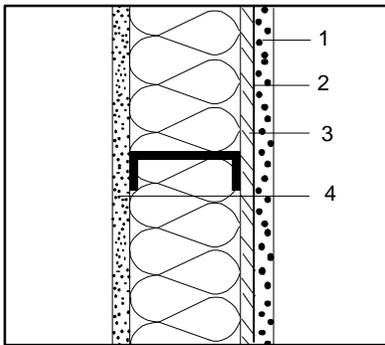
Framing Adjustment Calculation:

$$\left[\frac{1/14.535}{1+R^c} \times \left(\frac{1-12/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/5.00}{1+R^f} \times \left(\frac{12/100}{Fr.\% \div 100} \right) \right] = \frac{0.085}{1/0.085}$$

0.085
Total U-Value

= $\frac{10.620}{\text{Total R-Value}}$

Reference Name: W.13.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
24 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 13.00
Knock-out (%) 15.00
Web Thickness 0.060
Interior Flange 0.0
Exterior Flange 0.0

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

1.	Outside Surface Air Film
	0.875 in stucco
2.	Building paper (felt)
3.	0.75 in polyisocyanurate
4.	0.50 in gypsum or plaster board
5.	
6.	
7.	Inside Surface Air Film

R-Value	
0.170	
0.175	
0.060	
5.250	
0.450	

0.680	

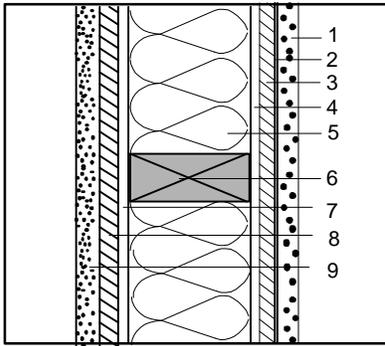
Calculation:

From EZFRAME = $\frac{0.087}{1/0.087}$

0.087
Total U-Value

= $\frac{11.460}{\text{Total R-Value}}$

Reference Name: WP.14.2x4.48



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wall Weight / sf:
(Packages only)

Floor
 Wall
 Ceiling/Roof
Wood
 2 x 4
 48 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 Floor/Ceiling 9% (48"o.c.)
 _____ 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

List of Construction Components

	Outside Surface Air Film
1.	0.875 in stucco
2.	Building paper (felt)
3.	0.375 in plywood
4.	0.875 in Furring Channel
5.	3 5/8 in EPS foam insulation @ R-3.85/in
6.	2X4 in fir framing
7.	0.875 in Furring Channel
8.	0.375 in plywood
9.	0.50 in gypsum or plaster board
	Inside Surface Air Film

Total Unadjusted R-Values:

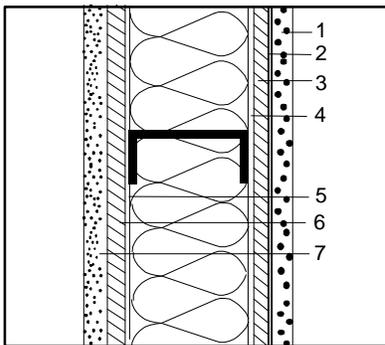
R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.060
0.470	0.470
0.800	0.800
13.956	-----
-----	3.465
0.800	0.800
0.470	0.470
0.450	0.450
0.680	0.680
18.031	7.540
R _c	R _f

Framing Adjustment Calculation:

$$\left[\frac{1/18.031}{1+R} \times \frac{(1-9/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/7.540}{1+R} \times \frac{(9/100)}{Fr.\% \div 100} \right] = \frac{1/0.062}{1+\text{Total U-Value}}$$

0.062
Total U-Value
 = $\frac{16.129}{\text{Total R-Value}}$

Reference Name: WP.14.2x4.48



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:
Framing Spacing:
Framing Size:

Cavity Insulation:

Insulation Tape R-value:

Floor
 Wall
 Ceiling/Roof
Metal
 48 "o.c."
 Actual Depth 3.625
 Actual Width 1.625
 R-value 14.00
 Knock-out (%) 15.00
 Web Thickness 0.060
 Interior Flange 0.0
 Exterior Flange 0.0

List of Construction Components

	Outside Surface Air Film
1.	0.875 in stucco
2.	Building paper (felt)
3.	1.00 in polyisocyanurate
4.	0.875 in Furring Channel
5.	0.875 in Furring Channel
6.	0.375 in plywood
7.	0.50 in gypsum or plaster board
	Inside Surface Air Film

R-Value

0.170
0.175
0.060
7.000
0.800
0.800
0.470
0.450
0.680

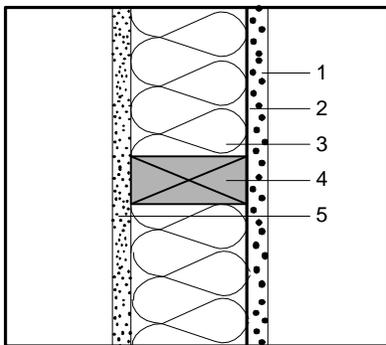
Calculation:

From EZFRAME

$$\frac{1/0.062}{1+\text{Total U-Value}}$$

0.062
Total U-Value
 = $\frac{16.26}{\text{Total R-Value}}$

Reference Name: W.15.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 4

Framing Spacing:

24 "o.c."

Framing Percentage:
(check one)

Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling: 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

	Outside Surface Air Film
1.	<u>0.875 in stucco</u>
2.	<u>Building paper (felt)</u>
3.	<u>R-15 fiberglass insulation</u>
4.	<u>2x4 in fir framing</u>
5.	<u>0.50 in gypsum or plaster board</u>
6.	
7.	
	Inside Surface Air Film

R-Value

Cavity (R _c)	Frame (R _f)
<u>0.170</u>	<u>0.170</u>
<u>0.175</u>	<u>0.175</u>
<u>0.060</u>	<u>0.060</u>
<u>15.000</u>	<u>-----</u>
<u>-----</u>	<u>3.465</u>
<u>0.450</u>	<u>0.450</u>
<u>-----</u>	<u>-----</u>
<u>0.680</u>	<u>0.680</u>
<u>16.535</u>	<u>5.00</u>
R_c	R_f

Total Unadjusted R-Values:

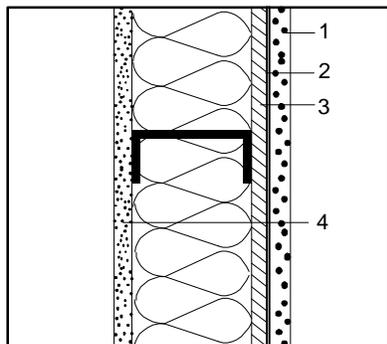
Framing Adjustment Calculation:

$$\left[\left(\frac{1/16.535}{1+R_c} \right) \times \left(\frac{1-12/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\left(\frac{1/5.00}{1+R_f} \right) \times \left(\frac{12/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.077}{1+Total\ U-Value} =$$

0.077
Total U-Value
12.987
Total R-Value

Reference Name: W.15.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

24 "o.c."

Framing Size:

Actual Depth 3.625

Actual Width 1.625

Cavity Insulation:

R-value 15.00

Knock-out (%) 15.00

Web Thickness 0.060

Insulation Tape R-value:

Interior Flange -----

Exterior Flange -----

List of Construction Components

	Outside Surface Air Film
1.	<u>0.875 in stucco</u>
2.	<u>Building paper (felt)</u>
3.	<u>1 in Polyisocyanurate</u>
4.	<u>0.50 in gypsum or plaster board</u>
5.	
6.	
7.	
	Inside Surface Air Film

R-Value

<u>0.170</u>
<u>0.175</u>
<u>0.060</u>
<u>7.000</u>
<u>0.450</u>
<u>-----</u>
<u>-----</u>
<u>0.680</u>

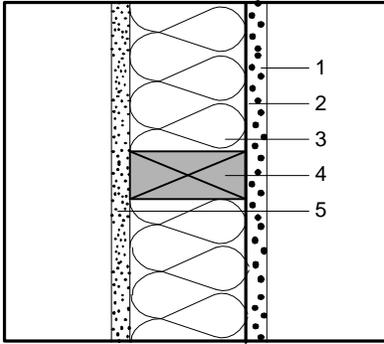
Calculation:

From EZFRAME

$$\frac{1/0.074}{1+Total\ U-Value} =$$

0.074
Total U-Value
13.470
Total R-Value

Reference Name: W.19.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 X 6

Framing Spacing:

16 "o.c."

Framing Percentage:
(check one)

Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

	Outside Surface Air Film
1.	0.875 in stucco
2.	Building paper (felt)
3.	R-19 fiberglass insulation
4.	2x6 in fir framing
5.	0.50 in gypsum or plaster board
6.	
7.	Inside Surface Air Film

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.060
17.800	-----
-----	5.445
0.450	0.450
-----	-----
0.680	0.680
19.335	6.980
R _c	R _f

Total Unadjusted R-Values:

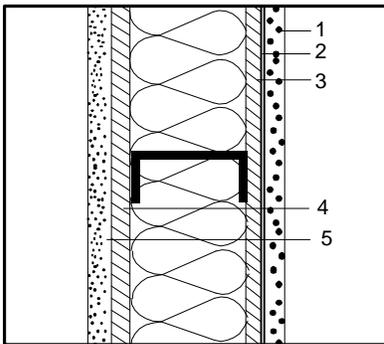
Framing Adjustment Calculation:

$$\left[\left(\frac{1}{1+R_c} \right) \times \left(\frac{1-15/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\left(\frac{1}{1+R_f} \right) \times \left(\frac{15/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.065}{1+Total\ U-Value} =$$

0.065
Total U-Value
15.385
Total R-Value

Reference Name: W.19.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c."

Framing Size:

Actual Depth 6.000
Actual Width 1.625

Cavity Insulation:

R-value 19.00

Insulation Tape R-value:

Knock-out (%) 15.00
Web Thickness 0.060
Interior Flange
Exterior Flange

List of Construction Components

	Outside Surface Air Film
1.	0.875 in stucco
2.	Building paper (felt)
3.	0.75 in polyisocyanurate
4.	0.50 in polyisocyanurate
5.	0.50 in gypsum or plaster board
6.	
7.	Inside Surface Air Film

R-Value

0.170
0.175
0.060
5.250
3.500
0.450

0.680

Calculation:

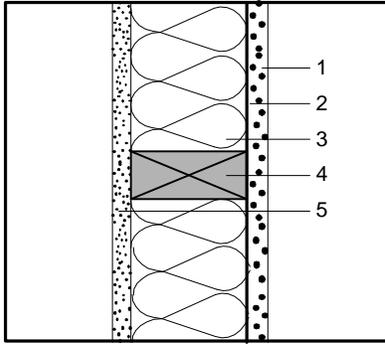
From EZFRAME =

0.064
Total U-Value

$$\frac{1/0.064}{1+Total\ U-Value} =$$

15.530
Total R-Value

Reference Name: W.19.2x6.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 X 6

Framing Spacing:

24 "o.c."

Framing Percentage:
(check one)

Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

	Outside Surface Air Film
1.	0.875 in stucco
2.	Building paper (felt)
3.	R-19 fiberglass insulation
4.	2x6 in fir framing
5.	0.50 in gypsum or plaster board
6.	
7.	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.060
17.800	-----
-----	5.445
0.450	0.450
-----	-----
0.680	0.680
19.335	6.980
R _c	R _f

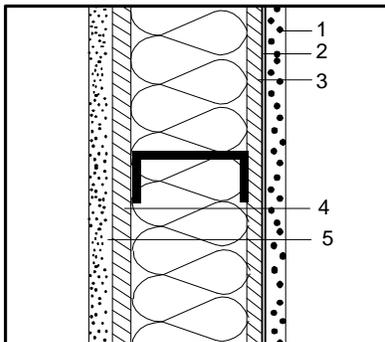
Framing Adjustment Calculation:

$$\left[\left(\frac{1}{19.335} \right) \times \left(\frac{1-12/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\left(\frac{1}{6.980} \right) \times \left(\frac{12/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.063}{1+\text{Total U-Value}} =$$

0.063
Total U-Value
15.873
Total R-Value

Reference Name: W.19.2x6.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

24 "o.c."

Framing Size:

Actual Depth 6.000

Cavity Insulation:

Actual Width 1.625

Insulation Tape R-value:

R-value 19.00

Knock-out (%) 15.00

Web Thickness 0.060

Interior Flange

Exterior Flange

List of Construction Components

	Outside Surface Air Film
1.	0.875 in stucco
2.	Building paper (felt)
3.	0.75 in polyisocyanurate
4.	0.50 in polyisocyanurate
5.	0.50 in gypsum board
6.	
7.	Inside Surface Air Film

R-Value

0.170
0.175
0.060
5.250
3.500
0.450

0.680

Calculation:

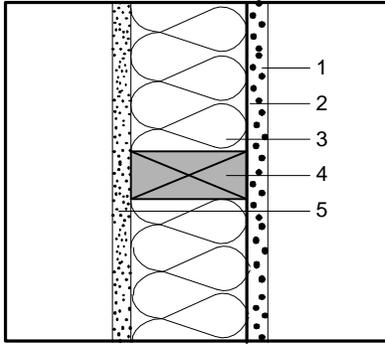
From EZFRAME =

0.060
Total U-Value

$$\frac{1/0.060}{1+\text{Total U-Value}} =$$

16.750
Total R-Value

Reference Name: W.21.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 6

Framing Spacing:

16 "o.c."

Framing Percentage:
(check one)

Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

	Outside Surface Air Film
1.	<u>0.875 in stucco</u>
2.	<u>Building paper (felt)</u>
3.	<u>R-21 fiberglass insulation</u>
4.	<u>2x6 in fir framing</u>
5.	<u>0.50 in gypsum or plaster board</u>
6.	
7.	
	Inside Surface Air Film

R-Value

Cavity (R _c)	Frame (R _f)
<u>0.170</u>	<u>0.170</u>
<u>0.175</u>	<u>0.175</u>
<u>0.060</u>	<u>0.060</u>
<u>21.000</u>	<u>-----</u>
<u>-----</u>	<u>5.445</u>
<u>0.450</u>	<u>0.450</u>
<u>-----</u>	<u>-----</u>
<u>0.680</u>	<u>0.680</u>
<u>22.535</u>	<u>6.980</u>
R_c	R_f

Total Unadjusted R-Values:

Framing Adjustment Calculation:

$$\left[\frac{1}{1+R} \times \left(\frac{1-15/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1}{1+R_f} \times \left(\frac{15/100}{Fr.\% \div 100} \right) \right] = \frac{1}{1+Total\ U-Value}$$

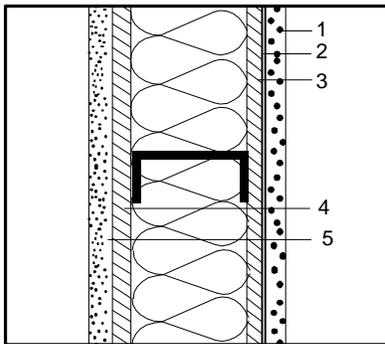
0.059

Total U-Value

16.949

Total R-Value

Reference Name: W.21.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c."

Framing Size:

Actual Depth 6.000

Actual Width 1.625

Cavity Insulation:

R-value 21.00

Knock-out (%) 15.00

Web Thickness 0.060

Insulation Tape R-value:

Interior Flange -----

Exterior Flange -----

List of Construction Components

	Outside Surface Air Film
1.	<u>0.875 in stucco</u>
2.	<u>Building paper (felt)</u>
3.	<u>1.0 in polyisocyanurate</u>
4.	<u>0.5 in polyisocyanurate</u>
5.	<u>0.50 in gypsum or plaster board</u>
6.	
7.	
	Inside Surface Air Film

R-Value

<u>0.170</u>
<u>0.175</u>
<u>0.060</u>
<u>7.000</u>
<u>3.500</u>
<u>0.450</u>
<u>-----</u>
<u>0.680</u>

Calculation:

From EZFRAME

0.057

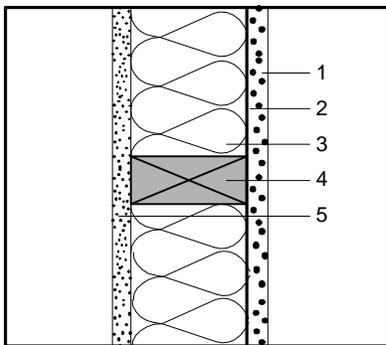
Total U-Value

$$\frac{1}{1+Total\ U-Value}$$

17.440

Total R-Value

Reference Name: W.21.2x6.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:

Framing Size:

Framing Spacing:

Framing Percentage:
(check one)

Floor
 Wall
 Ceiling/Roof

Wood

2 × 6
 24 "o.c."

Wall: _____ 15% (16"o.c.)
 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling _____ 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

Wall Weight / sf: NA
(Packages only)

List of Construction Components

	Outside Surface Air Film
1.	<u>0.875 in stucco</u>
2.	<u>Building paper (felt)</u>
3.	<u>R-21 fiberglass insulation</u>
4.	<u>2x6 in fir framing</u>
5.	<u>0.50 in gypsum or plaster board</u>
6.	_____
7.	_____
	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
<u>0.170</u>	<u>0.170</u>
<u>0.175</u>	<u>0.175</u>
<u>0.060</u>	<u>0.060</u>
<u>21.000</u>	<u>-----</u>
<u>-----</u>	<u>3.465</u>
<u>0.450</u>	<u>0.450</u>
_____	_____
<u>0.680</u>	<u>0.680</u>
<u>22.535</u>	<u>6.980</u>
R_c	R_f

Framing Adjustment Calculation:

$$\left[\left(\frac{1/22.535}{1+R_c} \right) \times \left(\frac{1-12/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\left(\frac{1/6.98}{1+R_f} \right) \times \left(\frac{12/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.056}{1+Total\ U-Value} =$$

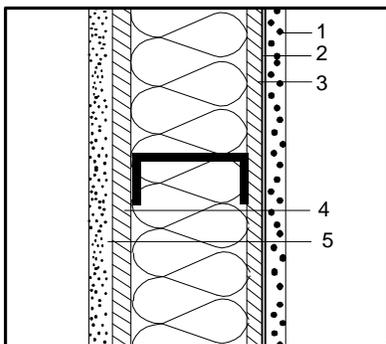
0.056

Total U-Value

17.857

Total R-Value

Reference Name: W.21.2x6.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:

Framing Spacing:

Framing Size:

Cavity Insulation:

Insulation Tape R-value:

Floor
 Wall
 Ceiling/Roof

Metal

24 "o.c."

Actual Depth 6.000
 Actual Width 1.625
 R-value 21.00
 Knock-out (%) 15.00
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

List of Construction Components

	Outside Surface Air Film
1.	<u>0.875 in stucco</u>
2.	<u>Building paper (felt)</u>
3.	<u>1.0 in polyisocyanurate</u>
4.	<u>0.5 in polyisocyanurate</u>
5.	<u>0.50 in gypsum or plaster board</u>
6.	_____
7.	_____
	Inside Surface Air Film

R-Value

<u>0.170</u>
<u>0.175</u>
<u>0.060</u>
<u>7.000</u>
<u>3.500</u>
<u>0.450</u>

<u>0.680</u>

Calculation:

From EZFRAME =

0.053

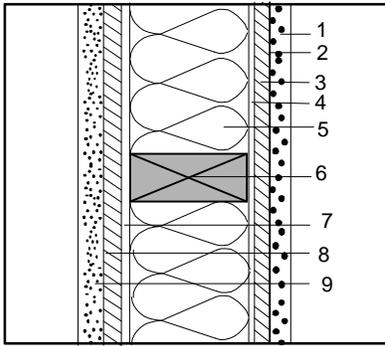
Total U-Value

18.720

Total R-Value

$$\frac{1/0.053}{1+Total\ U-Value} =$$

Reference Name: WP.22.2x6.48



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:

Framing Size:

Framing Spacing:

Framing Percentage:
(check one)

Floor
 Wall
 Ceiling/Roof

Wood

2 × 6
 48 "o.c."

Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

NA

Wall Weight / sf:
(Packages only)

List of Construction Components

1.	Outside Surface Air Film
2.	0.875 in stucco
3.	Building paper (felt)
4.	0.375 in plywood
5.	0.875 in Furring Channel
6.	R-21.656 EPS foam insulation
7.	2X6 in fir framing
8.	0.875 in Furring Channel
9.	0.375 in plywood
10.	0.50 in gypsum or plaster board
11.	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.175	0.175
0.060	0.060
0.470	0.470
0.800	0.800
21.656	-----
-----	5.445
0.800	0.800
0.470	0.470
0.450	0.450
0.680	0.680
25.731	9.520
R _c	R _f

Framing Adjustment Calculation:

$$\left[\frac{1/25.731}{1+R_c} \times \frac{(1-9/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/9.52}{1+R_f} \times \frac{(9/100)}{Fr.\% \div 100} \right] = \frac{1/0.044}{1+Total\ U-Value}$$

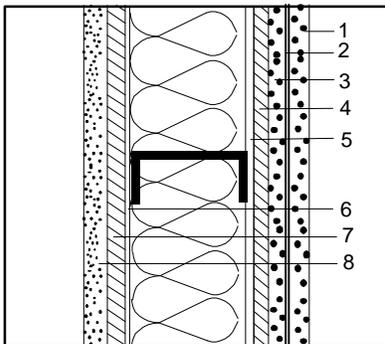
0.044

Total U-Value

22.727

Total R-Value

Reference Name: WP.22.2x6.48



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:

Framing Spacing:

Framing Size:

Cavity Insulation:

Insulation Tape R-value:

Floor
 Wall
 Ceiling/Roof

Metal

48 "o.c."

Actual Depth 6.000
 Actual Width 1.625
 R-value 21.700
 Knock-out (%) 15.00
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

List of Construction Components

1.	Outside Surface Air Film
2.	0.875 in stucco
3.	Building paper (felt)
4.	1.50 in polyisocyanurate
5.	0.50 in plywood
6.	0.875 in Furring channel
7.	0.875 in Furring channel
8.	0.50 in plywood
9.	0.50 in gypsum or plaster board
10.	Inside Surface Air Film

R-Value

0.170
0.175
0.060
10.500
0.630
0.800
0.800
0.630
0.450
0.680

Calculation:

From EZFRAME

$$\frac{1/0.044}{1+Total\ U-Value}$$

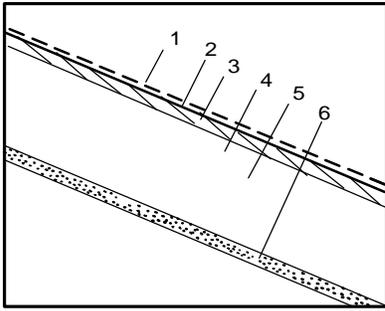
0.044

Total U-Value

22.83

Total R-Value

Reference Name: R.0.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Floor
 Wall
 Ceiling/Roof
Wood
 2 X 6
 16 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

List of Construction Components

Wall Weight / sf:
(Packages only)

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.5 in & greater air space; heat flow up
- 5. 2x6 in fir framing
- 6. 0.50 in gypsum or plaster board
- 7. Inside Surface Air Film

Total Unadjusted R-Values:

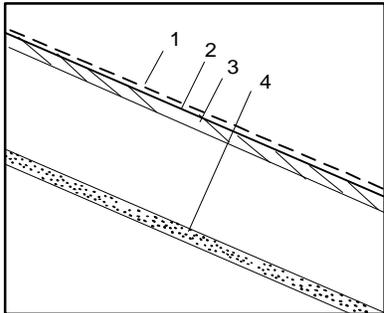
R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	-----
-----	5.445
0.450	0.450
0.610	0.610
3.150	7.795
R_c	R_f

Framing Adjustment Calculation:

$$\left[\frac{1}{3.150} \times \left(\frac{1-10/100}{1} \right) \right] + \left[\frac{1}{7.795} \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right] = \frac{1/0.298}{1 \div \text{Total U-Value}}$$

$$= \frac{0.298}{3.356} = \text{Total U-Value}$$

Reference Name: R.0.2X6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:
Framing Spacing:
Framing Size:

Cavity Insulation:

Insulation Tape R-value:

Floor
 Wall
 Ceiling/Roof
Metal
 16 "o.c."
 Actual Depth 6.000
 Actual Width 1.625
 R-value 0.800
 Knock-out (%) 15.00
 Web Thickness 0.06
 Interior Flange _____
 Exterior Flange _____

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 0.50 in gypsum or plaster board
- 5. _____
- 6. _____
- 7. Inside Surface Air Film

R-Value

0.170
0.440
0.060
0.630
0.450

0.620

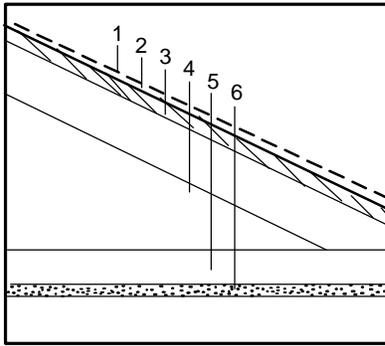
Calculation:

From EZFRAME

$$\frac{1/0.323}{1 \div \text{Total U-Value}}$$

$$= \frac{0.323}{3.090} = \text{Total U-Value}$$

Reference Name: R.0.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 × 4
24 "o.c."
Wall: _____ 15% (16"o.c.)
_____ 12% (24"o.c.)
_____ 9% (48"o.c.)
Floor/Ceiling _____ 10% (16"o.c.)
_____ 7% (24"o.c.)
_____ 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.5" & greater air space; heat sideways
- 5. 2x4 in fir framing
- 6. 0.50 in gypsum or plaster board
- 7. _____
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

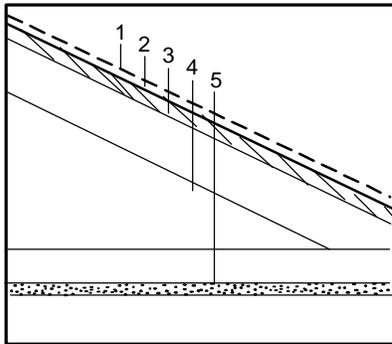
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
-----	3.465
0.450	0.450
_____	_____
0.610	0.610
3.150	6.615
R _c	R _f

Framing Adjustment Calculation:

$$\left[\frac{1/3.150}{1+R_c} \times \frac{(1-7/100)}{1-(Fr.\% +100)} \right] + \left[\frac{1/6.615}{1+R_f} \times \frac{(7/100)}{Fr.\% +100} \right] = \frac{1/0.306}{1+Total\ U-Value}$$

0.306
Total U-Value
= $\frac{3.268}{Total\ R-Value}$

Reference Name: R.0.2X4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:
Cavity Insulation:

Metal
24 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 0.800
Knock-out (%) 15.00
Web Thickness 0.060
Interior Flange _____
Exterior Flange _____

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.5" & greater air space; heat sideways
- 5. 0.50 in gypsum or plaster board
- 6. _____
- 7. _____
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
0.630
0.800
0.450

0.610

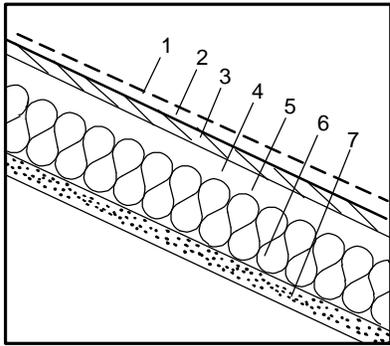
Calculation:

From EZFRAME

$$\frac{1/0.316}{1+Total\ U-Value}$$

0.316
Total U-Value
= $\frac{3.160}{Total\ R-Value}$

Reference Name: R.11.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 X 6
16 "o.c."
Wall: _____ 15% (16"o.c.)
_____ 12% (24"o.c.)
_____ 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
_____ 7% (24"o.c.)
_____ 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 2.0 in air space; heat flow up
- 5. 2X6 in fir framing
- 6. R-11 fiberglass insulation
- 7. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

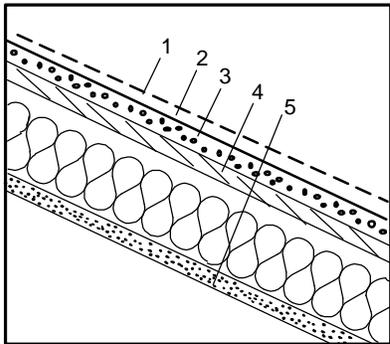
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.780	-----
-----	5.445
11.000	-----
0.450	0.450
0.610	0.610
14.130	7.795
R_c	R_f

Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \frac{1-10/100}{1-(Fr.\% \div 100)} \right] + \left[\frac{1}{1+R_f} \times \frac{10/100}{Fr.\% \div 100} \right] = \frac{1}{0.077}$$

0.077
Total U-Value
12.987
Total R-Value

Reference Name: R.11.2X6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:
Cavity Insulation:

Metal
16 "o.c."
Actual Depth 6.000
Actual Width 1.625
R-value 11.800
Knock-out (%) 15.000
Web Thickness 0.060
Interior Flange _____
Exterior Flange _____

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building paper (felt)
- 3. 0.75 in Polyisocyanurate
- 4. 0.625 in Plywood
- 5. 0.50 in gypsum or plaster board
- 6. _____
- 7. _____
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
5.250
0.780
0.450

0.620

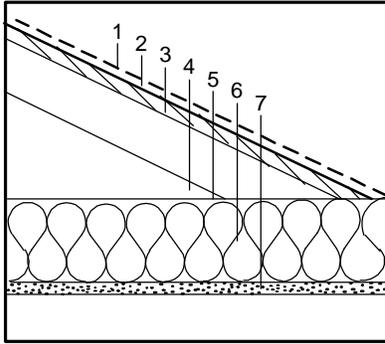
Calculation:

From EZFRAME

0.071
Total U-Value
14.060
Total R-Value

$$\frac{1}{0.071} = \frac{1}{1 \div \text{Total U-Value}}$$

Reference Name: R.11.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 X 4
24 "o.c."
Wall: _____ 15% (16"o.c.)
_____ 12% (24"o.c.)
_____ 9% (48"o.c.)
Floor/Ceiling _____ 10% (16"o.c.)
_____ 7% (24"o.c.)
_____ 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. R-11 fiberglass insulation
- 6. 2X4 in fir framing
- 7. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

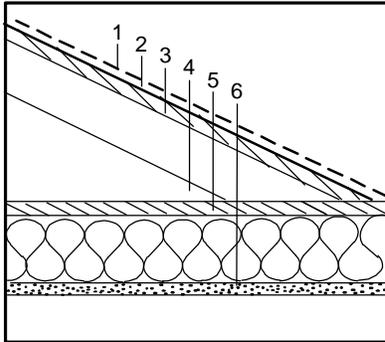
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
11.000	-----
-----	3.465
0.450	0.450
0.610	0.610
14.150	6.615
R_c	R_f

Framing Adjustment Calculation:

$$\left[\frac{1/14.150}{1+R_c} \times \frac{1-7/100}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/6.615}{1+R_f} \times \frac{7/100}{Fr.\% \div 100} \right] = \frac{1/0.077}{1+\text{Total U-Value}}$$

0.077
Total U-Value
= $\frac{12.987}{\text{Total R-Value}}$

Reference Name: R.11.2X4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:
Cavity Insulation:

Metal
24 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 11.000
Knock-out (%) 15.000
Web Thickness 0.060
Interior Flange _____
Exterior Flange _____

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. 0.75 in Polyisocyanurate
- 6. 0.50 in gypsum or plaster board
- 7. _____
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
0.630
0.800
5.250
0.450

0.610

Calculation:

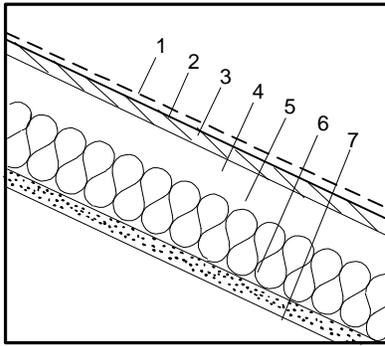
From EZFRAME

0.069
Total U-Value

$$\frac{1/0.069}{1+\text{Total U-Value}}$$

= $\frac{14.500}{\text{Total R-Value}}$

Reference Name: R.13.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 X 6
16 "o.c."
Wall: _____ 15% (16"o.c.)
_____ 12% (24"o.c.)
_____ 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
_____ 7% (24"o.c.)
_____ 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 2.0 in air space; heat flow up
- 5. 2X6 in fir framing
- 6. R-13 fiberglass insulation
- 7. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.780	-----
-----	5.445
13.000	-----
0.450	0.450
0.610	0.610
16.130	7.795
R_c	R_f

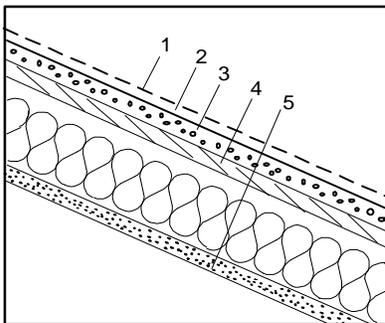
Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \frac{1-10/100}{1-(Fr.\% \div 100)} \right] + \left[\frac{1}{1+R_f} \times \frac{10/100}{Fr.\% \div 100} \right]$$

$$\frac{1}{1+0.069} = \frac{1}{1+14.493}$$

0.069
Total U-Value
14.493
Total R-Value

Reference Name: R.13.2X6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
16 "o.c."
Actual Depth 6.00
Actual Width 1.625
R-value 13.800
Knock-out (%) 15.000
Web Thickness 0.060
Interior Flange _____
Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building paper (felt)
- 3. 1.00 in polyisocyanurate
- 4. 0.50 in plywood
- 5. 0.50 in gypsum or plaster board
- 6. _____
- 7. _____
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
7.000
0.630
0.450

0.620

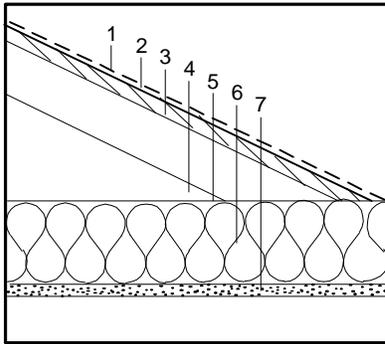
Calculation:

From EZFRAME

$$\frac{1}{1+0.062} = \frac{1}{1+16.130}$$

0.062
Total U-Value
16.130
Total R-Value

Reference Name: R.13.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:

Framing Size:

Framing Spacing:

Framing Percentage:
(check one)

Floor

Wall

Ceiling/Roof

Wood

2 × 4

24 "o.c."

Wall: _____ 15% (16"o.c.)

_____ 12% (24"o.c.)

_____ 9% (48"o.c.)

Floor/Ceiling _____ 10% (16"o.c.)

_____ 7% (24"o.c.)

_____ 4% (48"o.c.)

NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. R-13 fiberglass insulation
- 6. 2X4 in fir framing
- 7. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \frac{(1-Fr.\%)}{100} \right] + \left[\frac{1}{1+R_f} \times \frac{Fr.\%}{100} \right]$$

$$\frac{1}{1+R_c} \times \frac{(1-7)}{100} + \frac{1}{1+R_f} \times \frac{7}{100}$$

$$\frac{1}{1+16.150} \times \frac{3}{100} + \frac{1}{1+6.615} \times \frac{7}{100}$$

$$\frac{1}{1+0.069} = \frac{1}{14.492}$$

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
13.000	-----
-----	3.465
0.450	0.450
0.610	0.610
16.150	6.615
R_c	R_f

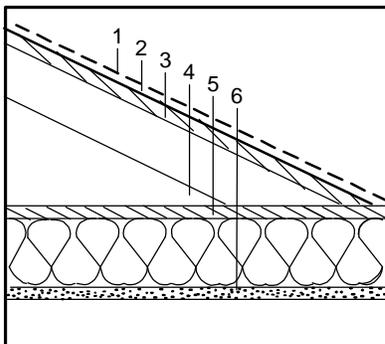
0.069

Total U-Value

14.492

Total R-Value

Reference Name: R.13.2X4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:

Framing Spacing:

Framing Size:

Cavity Insulation:

Insulation Tape R-value:

Floor

Wall

Ceiling/Roof

Metal

24 "o.c."

Actual Depth 3.625

Actual Width 1.625

R-value 13.000

Knock-out (%) 15.000

Web Thickness 0.060

Interior Flange _____

Exterior Flange _____

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. 0.75 in Polyisocyanurate
- 6. 0.50 in gypsum or plaster board
- 7. _____
- Inside Surface Air Film

Calculation:

From EZFRAME

$$\frac{1}{1+0.066} = \frac{1}{15.100}$$

R-Value

0.170
0.440
0.060
0.630
0.800
5.250
0.450

0.610

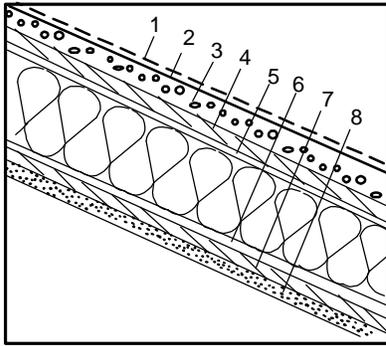
0.066

Total U-Value

15.100

Total R-Value

Reference Name: RP.14.2x4.48



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
- Wall
- Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

- Wood**
- 2 × 4
48 "o.c.
- Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
- Floor/Ceiling _____ 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
- NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.375 in plywood
- 4. 7/8 in furring channel
- 5. 2X4 in fir framing
- 6. 3 5/8 in EPS foam insulation
- 7. 7/8 in furring channel
- 8. 0.375 in plywood
- 9. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.470	0.470
0.800	0.800
-----	3.465
13.956	-----
0.800	0.800
0.470	0.470
0.450	0.450
0.610	0.610
18.226	7.735
R _c	R _f

Framing Adjustment Calculation:

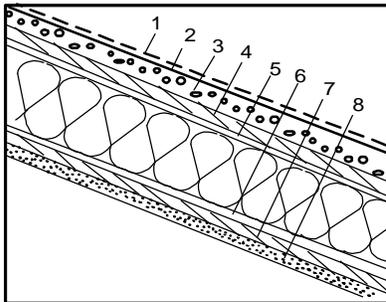
$$\left[\left(\frac{1}{18.226} \right) \times \left(\frac{1-4/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\left(\frac{1}{7.735} \right) \times \left(\frac{4/100}{Fr.\% \div 100} \right) \right]$$

$$= \frac{1/0.058}{1 + \text{Total U-Value}} = \frac{17.288}{\text{Total R-Value}}$$

0.058
Total U-Value

17.288
Total R-Value

Reference Name: RP.14.2x4.48



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
- Wall
- Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
- 48 "o.c.
- Actual Depth 3.625
 Actual Width 1.625
 R-value 14.000
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building paper
- 3. 3/4 in polyisocyanurate
- 4. 3/8 in plywood
- 5. 7/8 in furring channel
- 6. 7/8 in furring channel
- 7. 3/8 in plywood
- 8. 1/2 in gypsum or plaster board
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
5.250
0.470
0.800
0.800
0.800
0.470
0.620

Calculation:

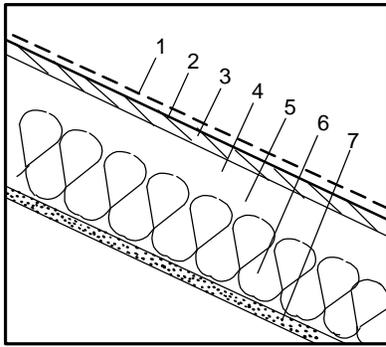
From EZFRAME

$$\frac{1/0.055}{1 + \text{Total U-Value}}$$

0.055
Total U-Value

18.130
Total R-Value

Reference Name: R.19.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 8
 16 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
 1. Asphalt shingle roofing
 2. Building paper (felt)
 3. 0.50 in plywood
 4. 1.0 in air space; heat flow up
 5. 2X8 in fir framing
 6. R-19 fiberglass insulation
 7. 0.50 in gypsum or plaster board
 Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.760	-----
-----	7.175
19.000	-----
0.450	0.450
0.610	0.610
22.110	9.528
R _c	R _f

Framing Adjustment Calculation:

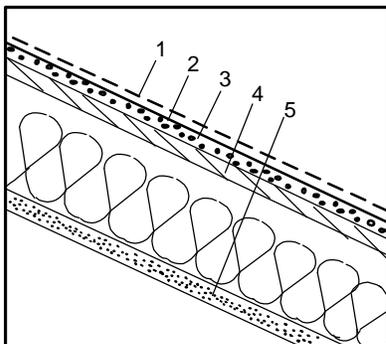
$$\left[\frac{1}{1+R_c} \times \frac{1-Fr.\%}{100} \right] + \left[\frac{1}{1+R_f} \times \frac{Fr.\%}{100} \right] = \frac{1}{0.051}$$

1/0.051
1+Total U-Value

0.051
Total U-Value

19.608
Total R-Value

Reference Name: R.19.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
 16 "o.c."
 Actual Depth 8.000
 Actual Width 1.625
 R-value 19.800
 Knock-out (%) 15.00
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
 1. Asphalt Shingle
 2. Building Paper
 3. 1.25 in Polyisocyanurate
 4. 0.5 in plywood
 5. 0.50 in Gypsum board
 6. _____
 7. _____
 Inside Surface Air Film

R-Value

0.170
0.440
0.060
8.750
0.630
0.450

0.620

Calculation:

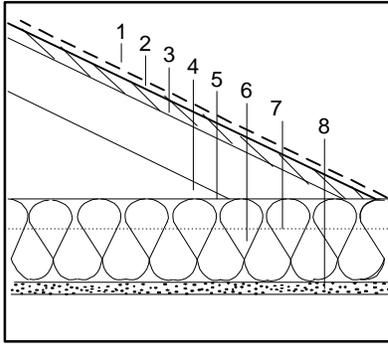
From EZFRAME

0.051
Total U-Value

$$\frac{1}{0.051} = \frac{1}{1+Total U-Value}$$

19.760
Total R-Value

Reference Name: R.19.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 X 4
24 "o.c."
Wall: _____ 15% (16"o.c.)
_____ 12% (24"o.c.)
_____ 9% (48"o.c.)
Floor/Ceiling _____ 10% (16"o.c.)
_____ 7% (24"o.c.)
_____ 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

1. 0.875 in stucco
 2. Building paper (felt)
 3. 0.50 in plywood
 4. 3.50 in & greater air space; heat flow up
 5. R-8 fiberglass insulation
 6. R-11 fiberglass insulation
 7. 2X4 in fir framing
 8. 0.50 in gypsum or plaster board
- Outside Surface Air Film
Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
8.000	8.000
11.000	-----
-----	3.465
0.450	0.450
0.610	0.610
22.150	14.615
R_c	R_f

Framing Adjustment Calculation:

$$\left[\frac{1/22.15}{1+R_c} \times \frac{(1-7/100)}{1-(Fr.\% +100)} \right] + \left[\frac{1/14.615}{1+R_f} \times \frac{(7/100)}{Fr.\% +100} \right] = \frac{1/0.047}{1+Total\ U-Value}$$

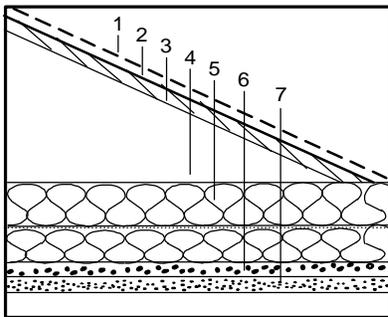
0.047

Total U-Value

21.277

Total R-Value

Reference Name: R.19.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
24 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 11.000
Knock-out (%) 15.000
Web Thickness 0.060
Interior Flange _____
Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

1. Asphalt Roofing
 2. Building paper (felt)
 3. 0.625 in Plywood
 4. 3.5 in Air, Ceiling
 5. R-8 fiberglass insulation
 6. 3/4 in polyisocyanurate
 7. 0.50 in Gypsum board
- Outside Surface Air Film
Inside Surface Air Film

R-Value

0.170
0.150
0.060
0.780
0.800
8.000
5.250
0.450
0.610

Calculation:

From EZFRAME

$$\frac{1/0.044}{1+Total\ U-Value}$$

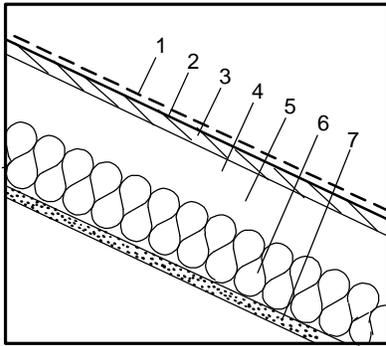
0.044

Total U-Value

22.670

Total R-Value

Reference Name: R.22.2x10.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

Wood
 2 × 10
 16 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

- Outside Surface Air Film
1. 0.875 in stucco
 2. Building paper (felt)
 3. 3.5" & greater air space; heat sideways
 4. 2x4 in fir framing
 5. 0.50 in gypsum or plaster board
 6. _____
 7. _____
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.790	-----
-----	9.158
22.000	-----
0.450	0.450
0.610	0.610
25.140	11.058
R_c	R_f

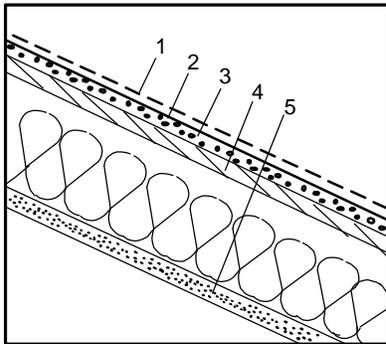
Framing Adjustment Calculation:

$$\left[\frac{1/25.14}{1+R_c} \times \frac{(1-10/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/11.058}{1+R_f} \times \frac{(10/100)}{Fr.\% \div 100} \right]$$

$$\frac{1/0.045}{1 \div \text{Total U-Value}}$$

= **0.045**
Total U-Value
 = $\frac{22.22}{\text{Total R-Value}}$

Reference Name: R.22.2x10.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:
Cavity Insulation:

Metal
 16 "o.c."
 Actual Depth 10.000
 Actual Width 1.625
 R-value 22.800
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
1. Asphalt Paper
 2. Building paper (felt)
 3. 1.50 in polyisocyanurate
 4. 0.50 in Plywood
 5. 0.50 in gypsum or plaster board
 6. _____
 7. _____
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
10.500
0.630
0.450

0.620

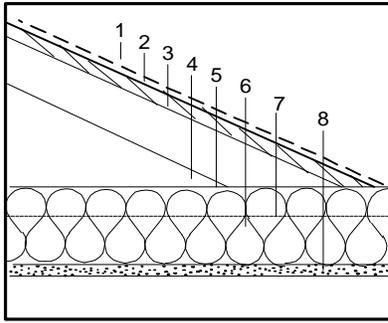
Calculation:

From EZFRAME

$$\frac{1/0.044}{1 \div \text{Total U-Value}}$$

= **0.044**
Total U-Value
 = $\frac{22.660}{\text{Total R-Value}}$

Reference Name: R.22.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 X 4
24 "o.c."
Wall: _____ 15% (16"o.c.)
_____ 12% (24"o.c.)
_____ 9% (48"o.c.)
Floor/Ceiling _____ 10% (16"o.c.)
_____ 7% (24"o.c.)
_____ 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space
- 5. R-11 fiberglass insulation
- 6. R-11 fiberglass insulation
- 7. 2X4 in fir framing
- 8. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

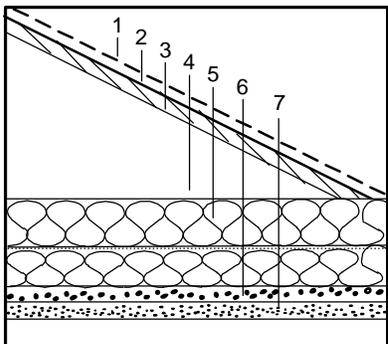
R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
11.000	11.000
11.000	-----
-----	3.465
0.450	0.450
0.610	0.610
25.150	17.615
R _c	R _f

Framing Adjustment Calculation:

$$\left[\frac{1/25.15}{1+R_c} \times \frac{(1-7/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/17.615}{1+R_f} \times \frac{(7/100)}{Fr.\% \div 100} \right] = \frac{1/0.041}{1+\text{Total U-Value}}$$

0.041
Total U-Value
= $\frac{24.390}{\text{Total R-Value}}$

Reference Name: R.22.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
24 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 11.000
Knock-out (%) 15.000
Web Thickness 0.060
Insulation Tape R-value: Interior Flange _____
Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space
- 5. R-11 fiberglass insulation
- 6. 0.75 in Polyisocyanurate
- 7. 0.50 in Gypsum Board
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
0.630
0.800
11.000
5.250
0.450
0.610

Calculation:

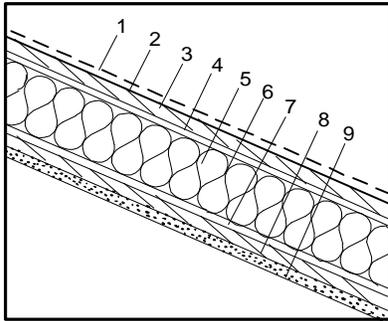
From EZFRAME

0.039
Total U-Value

$\frac{1/0.039}{1+\text{Total U-Value}}$

= $\frac{25.500}{\text{Total R-Value}}$

Reference Name: RP.22.2x6.48



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:

Framing Size:

Framing Spacing:

Framing Percentage:
(check one)

_____ Floor
 _____ Wall
 Ceiling/Roof

Wood

_____ 2 X _____ 6
 _____ 48 "o.c.

Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)

Floor/Ceiling _____ 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

_____ NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
1. Asphalt shingle roofing
 2. Building paper (felt)
 3. 0.375 in plywood
 4. 0.875 in furring channel
 5. 5 5/8 in EPS foam insulation
 6. 2X6 in fir framing
 7. 0.875 in furring channel
 8. 0.375 in plywood
 9. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.470	0.800
0.800	0.800
21.656	-----
-----	5.445
0.800	0.800
0.470	0.470
0.450	0.450
0.610	0.610
25.926	10.045
R _c	R _f

Framing Adjustment Calculation:

$$\left[\frac{1/25.926}{1+R_c} \times \left(\frac{1-4/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/10.045}{1+R_f} \times \left(\frac{4/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.041}{1+Total\ U-Value} =$$

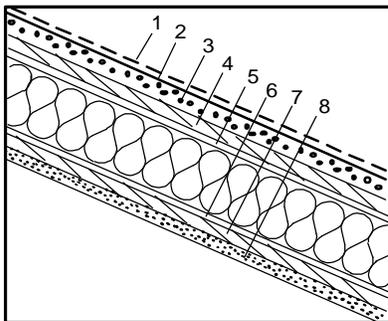
0.041

Total U-Value

24.384

Total R-Value

Reference Name: RP.22.2x6.48



Sketch of Construction Assembly

Assembly Type:
(check one)

Framing Material:

Framing Spacing:

Framing Size:

Cavity Insulation:

Insulation Tape R-value:

_____ Floor
 _____ Wall
 Ceiling/Roof

Metal

_____ 48 "o.c.

Actual Depth _____ 6.000

Actual Width _____ 1.625

R-value _____ 22.000

Knock-out (%) _____ 15.000

Web Thickness _____ 0.060

Interior Flange _____

Exterior Flange _____

List of Construction Components

- Outside Surface Air Film
1. Asphalt Shingle
 2. Building paper (felt)
 3. 1.00 in polyisocyanurate
 4. 0.375 in Plywood
 5. 0.875 in furring channel
 6. 0.875 in furring channel
 7. 0.375 in Plywood
 8. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Calculation:

From EZFRAME =

$$\frac{1/0.039}{1+Total\ U-Value} =$$

R-Value	
0.170	
0.440	
0.060	
7.000	
0.470	
0.800	
0.800	
0.470	
0.450	
0.620	

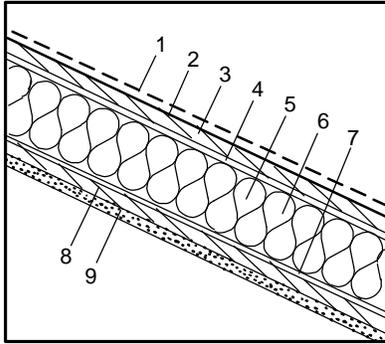
0.039

Total U-Value

25.460

Total R-Value

Reference Name: RP.28.2x8.48



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 X 8
48 "o.c."
Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.375 in plywood
- 4. 0.875 in furring channel
- 5. 7 3/8 in EPS foam insulation @ R-3.85/in
- 6. 2X8 in fir framing
- 7. 0.875 in furring channel
- 8. 0.375 in plywood
- 9. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.470	0.470
0.800	0.800
28.394	-----
-----	7.178
0.800	0.800
0.470	0.470
0.450	0.450
0.610	0.610
32.664	11.448
R _c	R _f

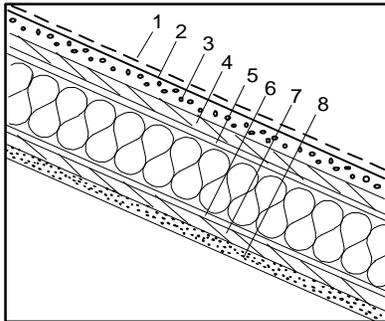
Framing Adjustment Calculation:

$$\left[\frac{1/32.664}{1+R_c} \times \left(\frac{1-4/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/11.448}{1+R_f} \times \left(\frac{4/100}{Fr.\% \div 100} \right) \right] = \frac{1/0.033}{1+Total\ U-Value}$$

0.033
Total U-Value

30.410
Total R-Value

Reference Name: RP.28.2x8.48



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
48 "o.c."
Actual Depth 8.000
Actual Width 1.625
R-value 28.394
Knock-out (%) 15.000
Web Thickness 0.060
Interior Flange
Exterior Flange

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt Shingle
- 2. Building paper (felt)
- 3. 1.75 in polyisocyanurate
- 4. 0.375 in Plywood
- 5. 0.875 in furring channel
- 6. 0.875 in furring channel
- 7. 0.375 in Plywood
- 8. 0.50 in gypsum or plaster board
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
12.250
0.470
0.800
0.800
0.470
0.450
0.620

Calculation:

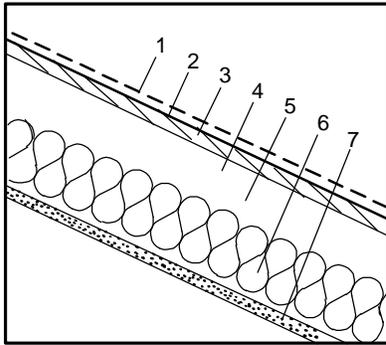
From EZFRAME

0.031
Total U-Value

$$\frac{1/0.031}{1+Total\ U-Value}$$

31.940
Total R-Value

Reference Name: R.30.2x12.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
- Wall
- Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 12

Framing Spacing:

16 "o.c.

Framing Percentage:
(check one)

- Wall: 15% (16"o.c.)
- 12% (24"o.c.)
- 9% (48"o.c.)
- Floor/Ceiling: 10% (16"o.c.)
- 7% (24"o.c.)
- 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 1.75 in air space; heat flow up
- 5. 2X12 in fir framing
- 6. R-30 fiberglass insulation
- 7. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.780	-----
-----	11.138
30.000	-----
0.450	0.450
0.610	0.610
33.130	13.488
R_c	R_f

Framing Adjustment Calculation:

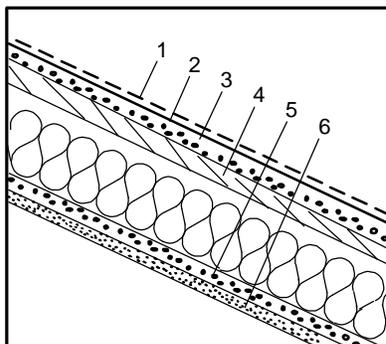
$$\left[\left(\frac{1}{33.130} \right) \times \left(\frac{1-10/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\left(\frac{1}{13.488} \right) \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right]$$

$$= \frac{1/0.034}{1+\text{Total U-Value}}$$

0.034
Total U-Value

29.412
Total R-Value

Reference Name: R.30.2x12.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
- Wall
- Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c.

Framing Size:

Actual Depth 12.00

Actual Width 1.625

Cavity Insulation:

R-value 30.8

Knock-out (%) 15.00

Web Thickness 0.060

Insulation Tape R-value:

Interior Flange

Exterior Flange

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building Paper
- 3. 1.50 in Polyisocyanurate
- 4. 0.50 in plywood
- 5. 1.00 in Polyisocyanurate
- 6. 0.50 in gypsum or plaster board
- 7. Inside Surface Air Film

R-Value

0.170
0.440
0.060
10.50
0.62
7.00
0.45
0.620

Calculation:

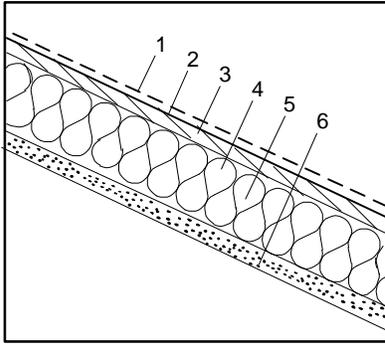
From EZFRAME

0.032
Total U-Value

$$\frac{1/0.032}{1+\text{Total U-Value}}$$

31.64
Total R-Value

Reference Name: R.30.2x10.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 X 10
16 "o.c."
Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 2x10 in fir framing
- 5. R-30c fiberglass insulation (8.5" thkns)
- 6. 0.50 in gypsum or plaster board
- 7. Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
-----	9.158
30.000	-----
0.450	0.450
0.610	0.610
32.350	11.508
R _c	R _f

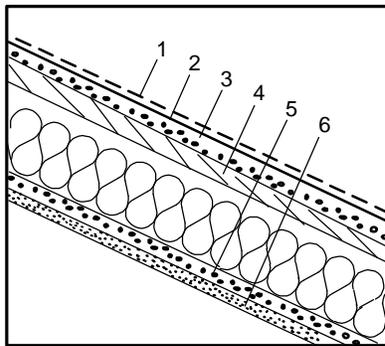
Framing Adjustment Calculation:

$$\left[\left(\frac{1}{32.350} \right) \times \left(\frac{1-10/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\left(\frac{1}{11.508} \right) \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right] = 1/0.036$$

$$\frac{1/0.036}{1+\text{Total U-Value}} = \text{Total U-Value}$$

0.036
Total U-Value
27.778
Total R-Value

Reference Name: R.30.2x10.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:
Cavity Insulation:

Metal
16 "o.c."
Actual Depth 10.00
Actual Width 1.625
R-value 30.80
Knock-out (%) 15.00
Web Thickness 0.060
Interior Flange
Exterior Flange

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. Building Paper
- 3. 1.50 in Polyisocyanurate
- 4. 0.50 in plywood
- 5. 0.75 in Polyisocyanurate
- 6. 0.50 in gypsum or plaster board
- 7. Inside Surface Air Film

R-Value

0.170
0.440
0.060
10.50
0.62
5.25
0.45
0.620

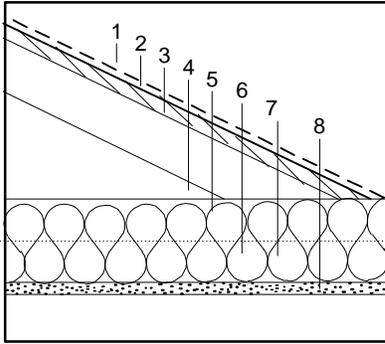
Calculation:

From EZFRAME = 1/0.034

$$\frac{1/0.034}{1+\text{Total U-Value}} = \text{Total U-Value}$$

0.034
Total U-Value
29.220
Total R-Value

Reference Name: R.30.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 X 4

Framing Spacing:

24 "o.c.

Framing Percentage:
(check one)

- Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

- Outside Surface Air Film
1. Asphalt shingle roofing
 2. Building paper (felt)
 3. 0.50 in plywood
 4. 3.50 in & greater air space
 5. R-19 fiberglass insulation
 6. R-11 fiberglass insulation
 7. 2X4 in fir framing
 8. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
19.000	19.000
11.000	-----
-----	3.465
0.450	0.450
0.610	0.610
33.150	25.615
R _c	R _f

Framing Adjustment Calculation:

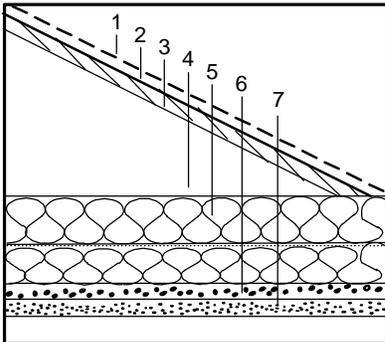
$$\left[\frac{1}{1+R_c} \times \frac{(1-Fr.\%)}{100} \right] + \left[\frac{1}{1+R_f} \times \frac{Fr.\%}{100} \right]$$

$$\frac{1}{1+0.031}$$

0.031
Total U-Value

32.481
Total R-Value

Reference Name: R.30.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

24 "o.c.

Framing Size:

Actual Depth 3.625

Actual Width 1.625

Cavity Insulation:

R-value 11.00

Knock-out (%) 15.00

Web Thickness 0.060

Insulation Tape R-value:

Interior Flange

Exterior Flange

List of Construction Components

- Outside Surface Air Film
1. Asphalt shingle roofing
 2. Building paper (felt)
 3. 0.50 in plywood
 4. 3.50 in & greater air space
 5. R-19 fiberglass insulation
 6. 0.75 in Polyisocyanurate
 7. 0.50 in Gypsum Board
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
0.630
0.800
19.000
5.250
0.450
0.680

Calculation:

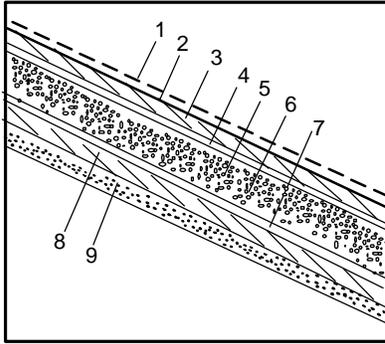
From EZFRAME

0.030
Total U-Value

$$\frac{1}{1+0.030}$$

33.52
Total R-Value

Reference Name: RP.35.2x10.48



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
- Wall
- Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

- Wood**
- 2 × 10
48 "o.c.
- Wall: 15% (16"o.c.)
 12% (24"o.c.)
 9% (48"o.c.)
 10% (16"o.c.)
 7% (24"o.c.)
 4% (48"o.c.)
- Floor/Ceiling
- NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.375 in plywood
- 4. 0.875 furring channel
- 5. 4 in EPS foam insulation
- 6. 2x10 in fir framing
- 7. 0.875 furring channel
- 8. 0.375 in plywood
- 9. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.470	0.470
0.800	0.800
35.000	-----
-----	9.158
0.800	0.800
0.470	0.470
0.450	0.450
0.610	0.610
39.270	13.426
R _c	R _f

Framing Adjustment Calculation:

$$\left[\frac{1/39.270}{1+R_c} \times \left(\frac{1-4/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/13.426}{1+R_f} \times \left(\frac{4/100}{Fr.\% \div 100} \right) \right] = 0.027$$

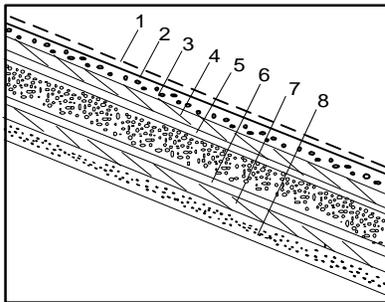
$$\frac{1/0.027}{1+Total\ U-Value} = 37.037$$

0.027

Total U-Value

Total R-Value

Reference Name: RP.35.2x10.48



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
- Wall
- Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
- 48 "o.c.
- Actual Depth 10.000
 Actual Width 1.625
 R-value 35.000
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange
 Exterior Flange

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 2.25 in polyisocyanurate
- 4. 0.375 in plywood
- 5. 0.875 in furring channel
- 6. 0.875 in furring channel
- 7. 0.375 in plywood
- 8. 0.50 in gypsum or plaster board
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
15.750
0.470
0.800
0.800
0.470
0.450
0.680

Calculation:

From EZFRAME

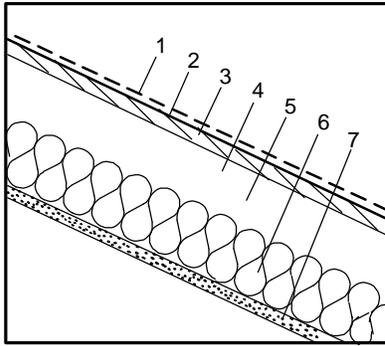
$$\frac{1/0.026}{1+Total\ U-Value}$$

0.026

Total U-Value

Total R-Value

Reference Name: R.38.2x14.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
- Wall
- Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

- Wood**
- 2 × 14
16 "o.c.
- Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
- NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 1.25 in air space; heat flow up
- 5. 2X14 in fir framing
- 6. R-38 fiberglass insulation
- 7. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.760	-----
-----	13.118
38.000	-----
0.450	0.450
0.610	0.610
41.110	15.468
R _c	R _f

Framing Adjustment Calculation:

$$\left[\frac{1}{41.110} \times \left(\frac{1-10/100}{1-R_c} \right) \right] + \left[\frac{1}{15.468} \times \left(\frac{10/100}{1-R_f} \right) \right] = \frac{1}{0.028}$$

1/0.028

1÷Total U-Value

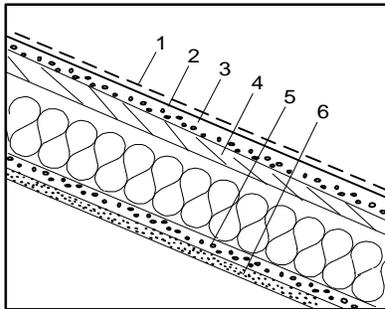
0.028

Total U-Value

35.714

Total R-Value

Reference Name: R.38.2x14.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
- Wall
- Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
- 16 "o.c.
- Actual Depth 14.000
 Actual Width 1.625
 R-value 38.800
 Knock-out (%) 15.00
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt Shingle
- 2. Building paper (felt)
- 3. 1.50 in Polyisocyanurate
- 4. 0.50 in Plywood
- 5. 1.50 in Polyisocyanurate
- 6. 0.50 in gypsum or plaster board
- 7. _____
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
10.500
0.630
10.500
0.450

0.620

Calculation:

From EZFRAME

0.027

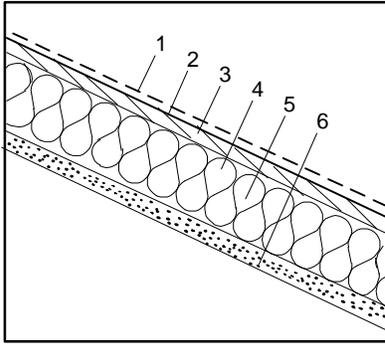
Total U-Value

$$\frac{1}{0.027} = \frac{1}{1 \div \text{Total U-Value}}$$

36.95

Total R-Value

Reference Name: R.38.2x12.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 X 12
16 "o.c."
Wall: _____ 15% (16"o.c.)
_____ 12% (24"o.c.)
_____ 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
_____ 7% (24"o.c.)
_____ 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 2X12 in fir framing
- 5. R-38 fiberglass insulation
- 6. 0.50 in gypsum or plaster board
- 7. _____
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

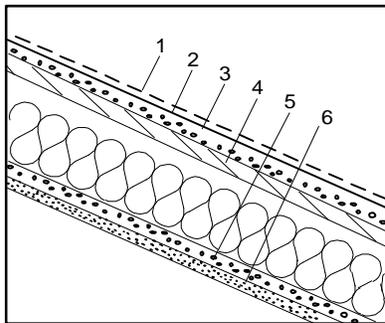
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
-----	11.138
37.000	-----
0.450	0.450
_____	_____
0.610	0.610
39.350	13.488
R _c	R _f

Framing Adjustment Calculation:

$$\left[\left(\frac{1}{39.350} \right) \times \left(\frac{1-10/100}{1-R_c} \right) \right] + \left[\left(\frac{1}{13.488} \right) \times \left(\frac{10/100}{1-R_f} \right) \right] = \frac{1/0.030}{1+\text{Total U-Value}}$$

0.030
Total U-Value
33.333
Total R-Value

Reference Name: R.38.2x12.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
16 "o.c."
Actual Depth 12.000
Actual Width 1.625
R-value 38.800
Knock-out (%) 15.000
Web Thickness 0.060
Interior Flange _____
Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt Shingle
- 2. Building paper (felt)
- 3. 1.50 in polyisocyanurate
- 4. 0.625 in plywood
- 5. 1.00 in polyisocyanurate
- 6. 0.625 in gypsum or plaster board
- 7. _____
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
10.50
0.780
7.00
0.560

0.620

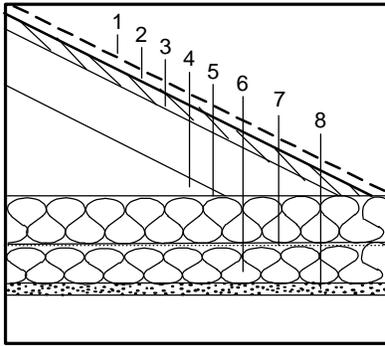
Calculation:

From EZFRAME

$$\frac{1/0.030}{1+\text{Total U-Value}}$$

0.030
Total U-Value
33.38
Total R-Value

Reference Name: R.38.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 4
 24 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling _____ 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. R-27 fiberglass insulation
- 6. R-11 fiberglass insulation
- 7. 2X4 in fir framing
- 8. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
27.000	27.000
11.000	-----
-----	3.465
0.450	0.450
0.610	0.610
41.150	33.615
R_c	R_f

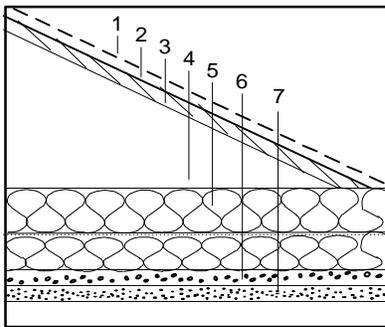
Framing Adjustment Calculation:

$$\left[\frac{1/41.150}{1+R_c} \times \left(\frac{1-7/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1/33.615}{1+R_f} \times \left(\frac{7/100}{Fr.\% \div 100} \right) \right] = \boxed{0.024}$$

Total U-Value

$$\frac{1/0.024}{1+Total\ U-Value} = \frac{41.667}{Total\ R-Value}$$

Reference Name: R.38.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
 24 "o.c."
 Actual Depth 3.625
 Actual Width 1.625
 R-value 11.00
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt Shingle
- 2. Building paper (felt)
- 3. 0.50 in Plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. R-27 fiberglass insulation
- 6. 1.00 in polyisocyanurate
- 7. 0.50 in gypsum or plaster board
- Inside Surface Air Film

R-Value

0.170
0.440
0.060
0.630
0.800
27.00
7.00
0.450
0.610

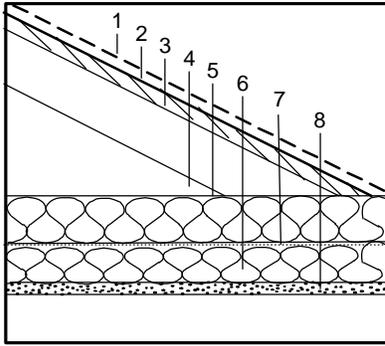
Calculation:

From EZFRAME = $\boxed{0.023}$

Total U-Value

$$\frac{1/0.023}{1+Total\ U-Value} = \frac{43.25}{Total\ R-Value}$$

Reference Name: R.49.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
(check one)

Wood
2 × 4
16 "o.c."
Wall: _____ 15% (16"o.c.)
_____ 12% (24"o.c.)
_____ 9% (48"o.c.)
Floor/Ceiling 10% (16"o.c.)
_____ 7% (24"o.c.)
_____ 4% (48"o.c.)
NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. R-38 fiberglass insulation
- 6. R-11 fiberglass insulation
- 7. 2X4 in fir framing
- 8. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
38.000	38.000
11.000	-----
-----	3.465
0.450	0.450
0.610	0.610
52.150	44.615
R _c	R _f

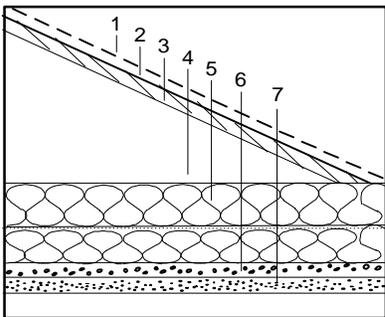
Framing Adjustment Calculation:

$$\left[\frac{1/52.150}{1+R_c} \times \frac{(1-10/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/44.615}{1+R_f} \times \frac{(10/100)}{Fr.\% \div 100} \right] = \frac{1/0.019}{1+\text{Total U-Value}}$$

0.019
Total U-Value

52.632
Total R-Value

Reference Name: R.49.2x4.16



Sketch of Construction Assembly

Assembly Type:
(check one)

Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
16 "o.c."
Actual Depth 3.625
Actual Width 1.625
R-value 11.00
Knock-out (%) 15.00
Web Thickness 0.060
Insulation Tape R-value:
Interior Flange _____
Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle
- 2. 0.50 in plywood
- 3. 3.50 in air space
- 4. R-38 fiberglass insulation
- 5. 1.00 in polyisocyanurate
- 6. 0.50 in gypsum or plaster board
- 7. Inside Surface Air Film

R-Value

0.170
0.440
0.630
0.800
38.00
7.000
0.450

0.610

Calculation:

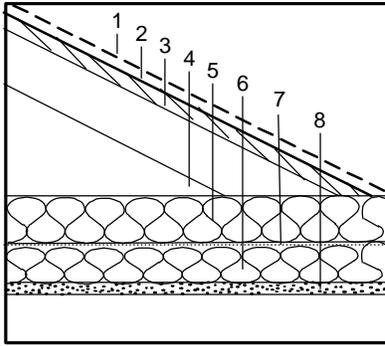
From EZFRAME =

0.019
Total U-Value

53.02
Total R-Value

$$\frac{1/0.019}{1+\text{Total U-Value}}$$

Reference Name: R.49.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 4
 24 "o.c.
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling _____ 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt shingle roofing
- 2. Building paper (felt)
- 3. 0.50 in plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. R-38 fiberglass insulation
- 6. R-11 fiberglass insulation
- 7. 2X4 in fir framing
- 8. 0.50 in gypsum or plaster board
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
0.440	0.440
0.060	0.060
0.620	0.620
0.800	0.800
38.000	38.000
11.000	-----
-----	3.465
0.450	0.450
0.610	0.610
52.150	44.615
R_c	R_f

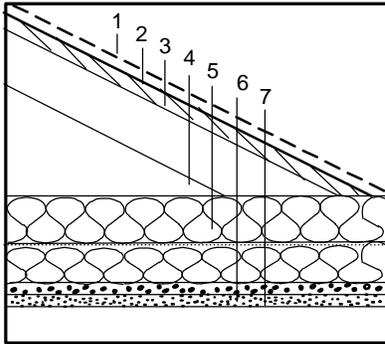
Framing Adjustment Calculation:

$$\left[\frac{1/52.15}{1+R} \right] \times \left[\frac{1-7/100}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/44.615}{1+R} \right] \times \left[\frac{7/100}{Fr.\% \div 100} \right] = \boxed{0.019}$$

Total U-Value

$$\frac{1/0.019}{1+Total\ U-Value} = \frac{52.632}{Total\ R-Value}$$

Reference Name: R.49.2x4.24



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
 24 "o.c.
 Actual Depth 3.625
 Actual Width 1.625
 R-value 11.00
 Knock-out (%) 15.00
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
- 1. Asphalt Shingle
- 2. Building paper (felt)
- 3. 0.50 in Plywood
- 4. 3.50 in & greater air space; heat flow up
- 5. R-38 fiberglass insulation
- 6. 0.25 in Polyisocyanurate
- 7. 0.75 in gypsum or plaster board
- Inside Surface Air Film

R-Value

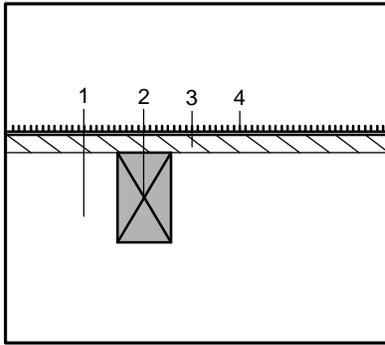
0.170
0.440
0.060
0.630
0.800
38.000
1.750
0.680
0.610

Calculation:

From EZFRAME = $\frac{1/0.018}{1+Total\ U-Value} = \frac{54.250}{Total\ R-Value}$

0.018
Total U-Value

Reference Name: FC.0.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 6
 16 "o.c.
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
 1. Effective R-value of vented crawlspace _____
 2. 2X6 in fir framing _____
 3. 0.625 in plywood _____
 4. Carpet & Pad _____
 5. _____
 6. _____
 7. _____
 Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
6.000	6.000
-----	5.445
0.770	0.770
2.080	2.080
_____	_____
_____	_____
0.920	0.920
3.940	9.385
R_c	R_f

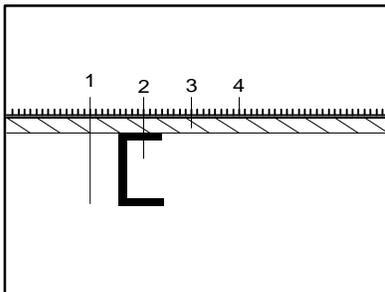
Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \frac{(1-10/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1}{1+R_f} \times \frac{(10/100)}{Fr.\% \div 100} \right] = \frac{1}{0.097}$$

0.097
Total U-Value

$$\frac{1}{0.097} = \frac{10.309}{\text{Total R-Value}}$$

Reference Name: FC.0.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
 16 "o.c.
 Actual Depth 6.000
 Actual Width 1.625
 R-value 0.800
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
 1. Effective R-value of vented crawlspace _____
 2. 0.625 in plywood _____
 3. Carpet & Pad _____
 4. _____
 5. _____
 6. _____
 7. _____
 Inside Surface Air Film

R-Value

0.170
6.000
0.780
2.080

0.920

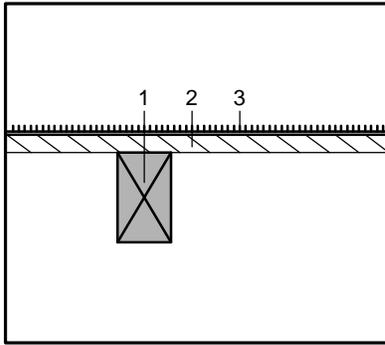
Calculation:

From EZFRAME

0.094
Total U-Value

$$\frac{1}{0.094} = \frac{10.680}{\text{Total R-Value}}$$

Reference Name: FX.0.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 6

Framing Spacing:

16 "o.c.

Framing Percentage:
(check one)

- Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

	Outside Surface Air Film
1.	2X6 in fir framing
2.	0.625 in plywood
3.	Carpet & Pad
4.	
5.	
6.	
7.	
	Inside Surface Air Film

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
----	5.445
0.770	0.770
2.080	2.080
0.920	0.920
3.940	9.385
R _c	R _f

Total Unadjusted R-Values:

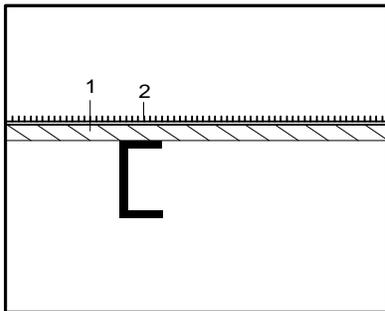
Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \left(\frac{1-10/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1}{1+R_f} \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.241}{1+Total\ U-Value} =$$

0.241
Total U-Value
 = $\frac{4.150}{Total\ R-Value}$

Reference Name: FX.0.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c.

Framing Size:

Actual Depth 6.000

Actual Width 1.625

R-value 0.800

Knock-out (%) 15.000

Web Thickness 0.060

Interior Flange _____

Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

	Outside Surface Air Film
1.	0.625 in plywood
2.	Carpet & pad
3.	
4.	
5.	
6.	
7.	
	Inside Surface Air Film

R-Value	
	0.170
	0.780
	2.08
	0.920

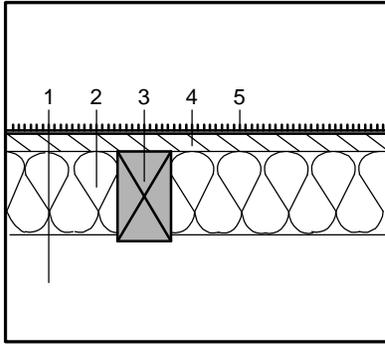
Calculation:

From EZFRAME =

0.253
Total U-Value
 = $\frac{3.950}{Total\ R-Value}$

$\frac{1/0.253}{1+Total\ U-Value} =$

Reference Name: FC.11.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 6

Framing Spacing:

16 "o.c.

Framing Percentage:
(check one)

- Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

1. Outside Surface Air Film
2. Effective R-value of vented crawlspace
3. R-11 fiberglass insulation
4. 2X6 in fir framing
5. 0.625 in plywood
6. Carpet & pad
7. _____
- _____ Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

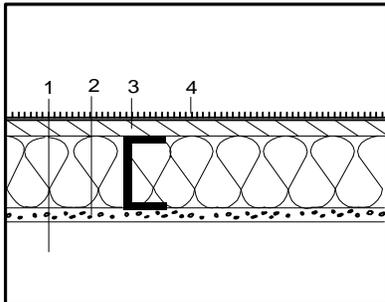
Cavity (R _c)	Frame (R _f)
0.170	0.170
6.000	6.000
11.000	-----
-----	5.445
0.770	0.770
2.080	2.080
-----	-----
-----	-----
0.920	0.920
20.940	15.385
R_c	R_f

Framing Adjustment Calculation:

$$\left[\frac{1}{1+20.940} \times \frac{(1-10/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1}{1+15.385} \times \frac{(10/100)}{Fr.\% \div 100} \right] = \frac{1/0.050}{1+Total\ U\text{-}Value}$$

$$= \frac{\boxed{0.050}}{20.00} = \frac{\text{Total U-Value}}{\text{Total R-Value}}$$

Reference Name: FC.11.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c.

Framing Size:

Actual Depth 6.000

Actual Width 1.625

Cavity Insulation:

R-value 11.000

Knock-out (%) 15.000

Web Thickness 0.060

Insulation Tape R-value:

Interior Flange _____

Exterior Flange _____

List of Construction Components

1. Outside Surface Air Film
2. Effective R-value of vented crawlspace
3. 0.75 in polyisocyanurate
4. 0.625 in plywood
5. Carpet & pad
6. _____
7. _____
- _____ Inside Surface Air Film

R-Value

0.170
6.000
5.250
0.780
2.080

0.920

Calculation:

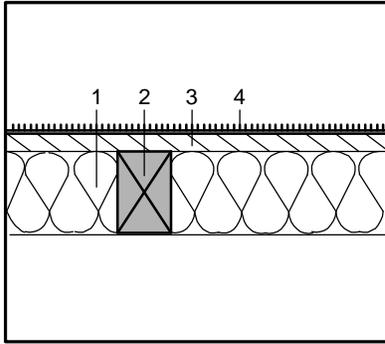
From EZFRAME

$$= \frac{\boxed{0.048}}{\text{Total U-Value}}$$

$$= \frac{1/0.048}{1+Total\ U\text{-}Value}$$

$$= \frac{21.030}{\text{Total R-Value}}$$

Reference Name: FX.11.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 6
 16 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
 1. R-11 fiberglass insulation
 2. 2X6 in fir framing
 3. 0.625 in Plywood
 4. Carpet & pad
 5. _____
 6. _____
 7. _____
 Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
11.000	-----
-----	5.445
0.770	0.770
2.080	2.080
-----	-----
-----	-----
0.920	0.920
14.940	9.385
R _c	R _f

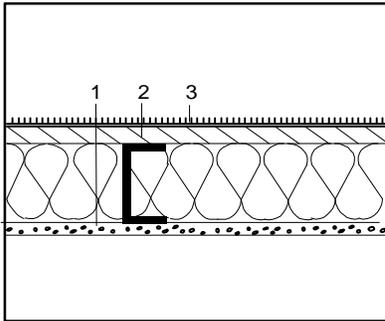
Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \frac{(1-10/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1}{1+R_f} \times \frac{(10/100)}{Fr.\% \div 100} \right] = \frac{1/0.071}{1+Total\ U-Value}$$

$$= \frac{0.071}{14.085}$$

Total U-Value
Total R-Value

Reference Name: FX.11.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:
Cavity Insulation:

- Metal**
 16 "o.c."
 Actual Depth 6.000
 Actual Width 1.625
 R-value 11.000
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
 1. 0.75 in polyisocyanurate
 2. 0.625 in plywood
 3. Carpet & pad
 4. _____
 5. _____
 6. _____
 7. _____
 Inside Surface Air Film

R-Value

0.170
5.250
0.780
2.080

0.920

Calculation:

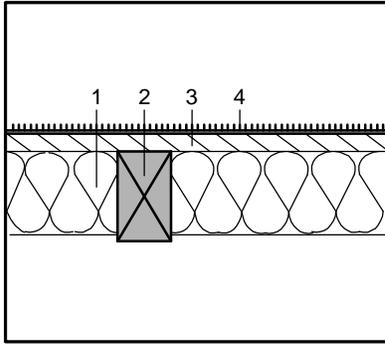
From EZFRAME

$$\frac{1/0.071}{1+Total\ U-Value}$$

$$= \frac{0.071}{14.16}$$

Total U-Value
Total R-Value

Reference Name: FX.13.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 6
 16 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
1. R-13 fiberglass insulation
 2. 2X6 in fir framing
 3. 0.625 in plywood
 4. Carpet & pad
 5. _____
 6. _____
 7. _____
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
13.000	-----
-----	5.445
0.770	0.770
2.080	2.080
_____	_____
_____	_____
_____	_____
0.920	0.920
16.940	9.385
R_c	R_f

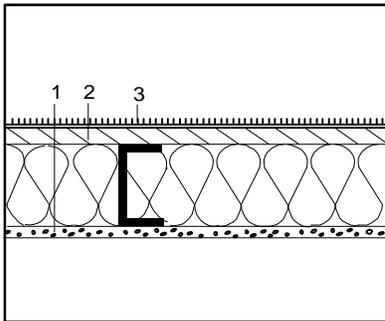
Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \left(\frac{1-10/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1}{1+R_f} \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.064}{1+\text{Total U-Value}}$$

0.064
Total U-Value
 =
 15.625
Total R-Value

Reference Name: FX.13.2x6.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
 16 "o.c."
 Actual Depth 6.000
 Actual Width 1.625
 R-value 13.000
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:
Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
1. 1.00 in polyisocyanurate
 2. 0.625 in plywood
 3. Carpet & pad
 4. _____
 5. _____
 6. _____
 7. _____
- Inside Surface Air Film

R-Value

0.170
7.000
0.780
2.080

0.920

Calculation:

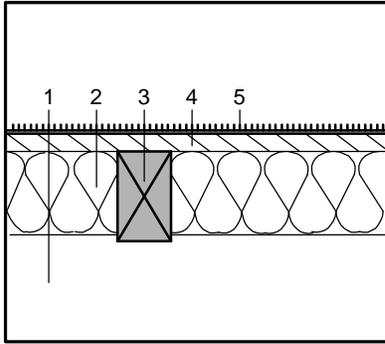
From EZFRAME =

0.058
Total U-Value

$$\frac{1/0.058}{1+\text{Total U-Value}}$$

=
 17.340
Total R-Value

Reference Name: FC.19.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 8
 16 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
 1. Effective R-value of vented crawlspace
 2. R-19 fiberglass insulation
 3. 7.25 in fir framing
 4. 0.625 in plywood
 5. Carpet & pad
 6. _____
 7. _____
 Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
6.000	6.000
19.000	-----
-----	7.178
0.770	0.770
2.080	2.080
-----	-----
-----	-----
0.920	0.920
28.940	17.118
R _c	R _f

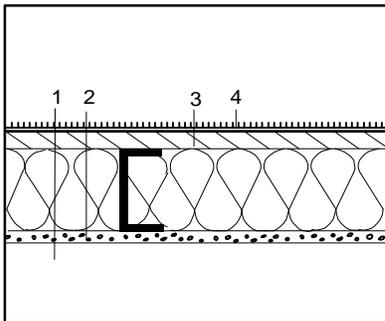
Framing Adjustment Calculation:

$$\left[\frac{1/14.535}{1+R_c} \times \frac{(1-10/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/17.118}{1+R_f} \times \frac{(10/100)}{Fr.\% \div 100} \right] = \frac{1/0.037}{1+\text{Total U-Value}}$$

$$= \frac{0.037}{27.027}$$

Total U-Value
Total R-Value

Reference Name: FC.19.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:
Cavity Insulation:

- Metal**
 16 "o.c."
 Actual Depth 8.00
 Actual Width 1.625
 R-value 19.000
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
 1. Effective R-value of vented crawlspace
 2. 1.50 in polyisocyanurate
 3. 0.625 in plywood
 4. Carpet & pad
 5. _____
 6. _____
 7. _____
 Inside Surface Air Film

R-Value

0.170
6.000
10.500
0.780
2.080

0.920

Calculation:

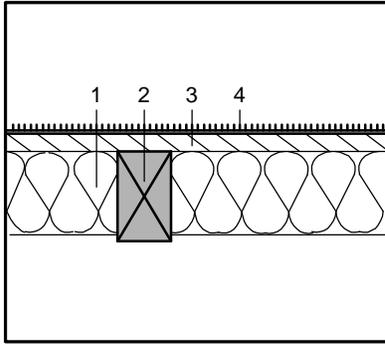
From EZFRAME

$$\frac{1/0.035}{1+\text{Total U-Value}}$$

$$= \frac{0.035}{28.700}$$

Total U-Value
Total R-Value

Reference Name: FX.19.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 8

Framing Spacing:

16 "o.c."

Framing Percentage:
(check one)

- Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

	Outside Surface Air Film
1.	R-19 fiberglass insulation
2.	7.25 in fir framing
3.	0.625 in plywood
4.	Carpet & pad
5.	
6.	
7.	
	Inside Surface Air Film

Total Unadjusted R-Values:

R-Value

Cavity (R _c)	Frame (R _f)
0.170	0.170
19.000	-----
-----	7.178
0.770	0.770
2.080	2.080
0.920	0.920
22.940	11.118
R_c	R_f

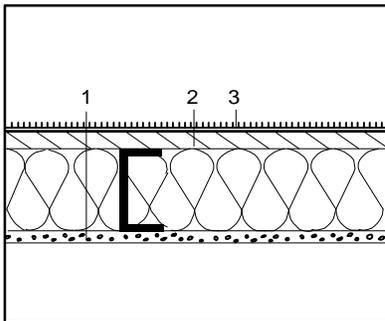
Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \left(\frac{1-10/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1}{1+R_f} \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.049}{1+\text{Total U-Value}} =$$

0.049
Total U-Value
 20.408
Total R-Value

Reference Name: FX.19.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c."

Framing Size:

Actual Depth 8.00

Actual Width 1.625

Cavity Insulation:

R-value 19.000

Knock-out (%) 15.000

Web Thickness 0.060

Insulation Tape R-value:

Interior Flange

Exterior Flange

List of Construction Components

	Outside Surface Air Film
1.	1.25 in polyisocyanurate
2.	0.625 in plywood
3.	Carpet & pad
4.	
5.	
6.	
7.	
	Inside Surface Air Film

R-Value

0.170
8.750
0.780
2.080
0.920

Calculation:

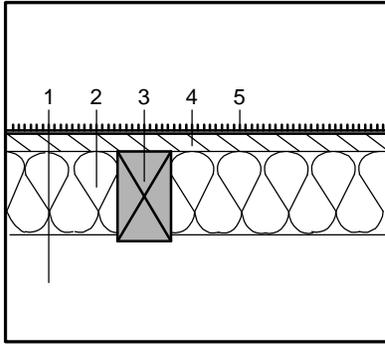
From EZFRAME =

0.048
Total U-Value

$$\frac{1/0.048}{1+\text{Total U-Value}} =$$

20.950
Total R-Value

Reference Name: FC.21.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 8
 16 "o.c."
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
 1. Effective R-value of vented crawlspace
 2. R-21 fiberglass insulation
 3. 7.25 in fir framing
 4. 0.625 in plywood
 5. Carpet & pad
 6. _____
 7. _____
 Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
6.000	6.000
21.000	-----
-----	7.178
0.770	0.770
2.080	2.080
-----	-----
-----	-----
0.920	0.920
30.940	17.118
R _c	R _f

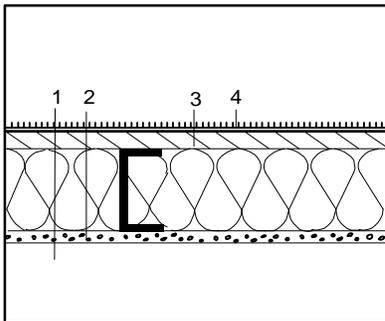
Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \left(\frac{1-10/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1}{1+R_f} \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right] =$$

$$\frac{1/0.035}{1+\text{Total U-Value}} =$$

0.035
Total U-Value
 28.571
Total R-Value

Reference Name: FC.21.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
 16 "o.c."
 Actual Depth 8.00
 Actual Width 1.625
 R-value 21.000
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:
Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
 1. Effective R-value of vented crawlspace
 2. 1.50 in polyisocyanurate
 3. 0.625 in plywood
 4. Carpet & pad
 5. _____
 6. _____
 7. _____
 Inside Surface Air Film

R-Value

0.170
6.000
10.50
0.780
2.080

0.920

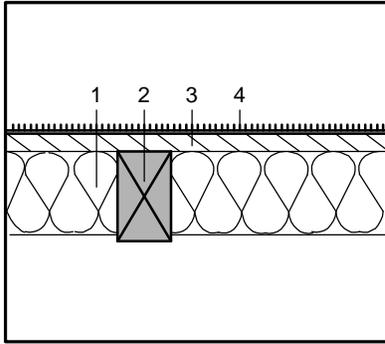
Calculation:

From EZFRAME =

0.034
Total U-Value
 29.080
Total R-Value

$$\frac{1/0.034}{1+\text{Total U-Value}} =$$

Reference Name: FX.21.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

Wood
 2 × 8
 16 "o.c.
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

1. Outside Surface Air Film
2. R-19 fiberglass insulation
3. 7.25 in fir framing
4. 0.625 in plywood
5. Carpet & pad
6. _____
7. _____
8. Inside Surface Air Film

Total Unadjusted R-Values:

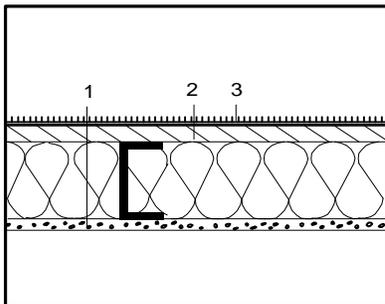
R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
21.000	-----
-----	7.178
0.780	0.780
2.080	2.080
-----	-----
-----	-----
0.920	0.920
22.950	11.128
R _c	R _f

Framing Adjustment Calculation:

$$\left[\frac{1/24.950}{1+R_c} \times \frac{(1-10/100)}{1-(Fr.\% \div 100)} \right] + \left[\frac{1/11.128}{1+R_f} \times \frac{(10/100)}{Fr.\% \div 100} \right] = \frac{1/0.045}{1+Total\ U-Value}$$

$$= \frac{0.045}{22.220} = \frac{Total\ U-Value}{Total\ R-Value}$$

Reference Name: FX.21.2x8.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

Metal
 16 "o.c.
 Actual Depth 8.00
 Actual Width 1.625
 R-value 21.000
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

1. Outside Surface Air Film
2. 1.50 in polyisocyanurate
3. 0.625 in plywood
4. Carpet & pad
5. _____
6. _____
7. _____
8. Inside Surface Air Film

R-Value

0.170
10.50
0.780
2.080

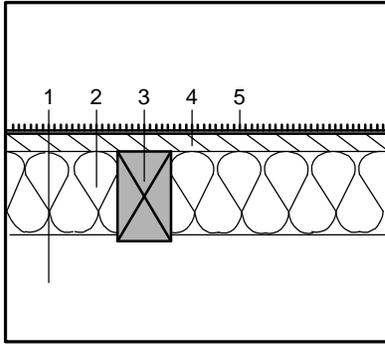
0.920

Calculation:

From EZFRAME

$$= \frac{0.043}{23.080} = \frac{Total\ U-Value}{Total\ R-Value}$$

Reference Name: FC.30.2x10.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Wood

Framing Size:

2 × 8

Framing Spacing:

16 "o.c."

Framing Percentage:
(check one)

- Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)

Wall Weight / sf:
(Packages only)

NA

List of Construction Components

- Outside Surface Air Film
1. Effective R-value of vented crawlspace
 2. R-30 fiberglass insulation
 3. 9.25 in fir framing
 4. 0.625 in plywood
 5. Carpet & pad
 6. _____
 7. _____
- Inside Surface Air Film

Total Unadjusted R-Values:

R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
6.000	6.000
30.000	-----
-----	9.158
0.770	0.770
2.080	2.080
-----	-----
-----	-----
0.920	0.920
39.940	19.098
R_c	R_f

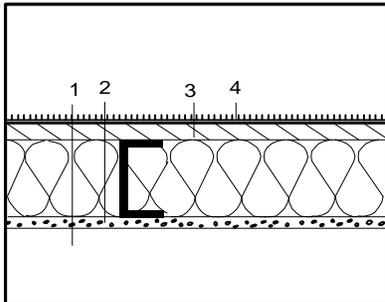
Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \left(\frac{1-10/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1}{1+R_f} \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right] = \frac{1/0.028}{1+\text{Total U-Value}}$$

$$= \frac{\mathbf{0.028}}{\mathbf{35.714}} = \mathbf{0.026}$$

Total U-Value
Total R-Value

Reference Name: FC.30.2x10.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:

Metal

Framing Spacing:

16 "o.c."

Framing Size:

Actual Depth 10.000

Actual Width 1.625

Cavity Insulation:

R-value 30.000

Knock-out (%) 15.000

Web Thickness 0.060

Insulation Tape R-value:

Interior Flange _____

Exterior Flange _____

List of Construction Components

- Outside Surface Air Film
1. Effective R-value of vented crawlspace
 2. 2.50 in polyisocyanurate
 3. 0.625 in plywood
 4. Carpet & pad
 5. _____
 6. _____
 7. _____
- Inside Surface Air Film

R-Value

0.170
6.000
17.50
0.780
2.080

0.920

Calculation:

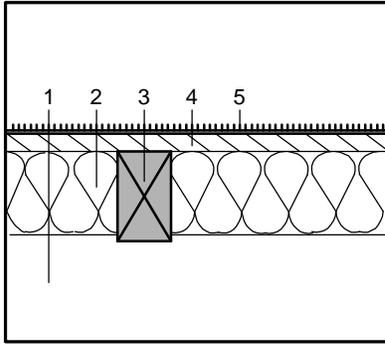
From EZFRAME

$$= \frac{\mathbf{0.026}}{\mathbf{38.110}} = \mathbf{0.026}$$

Total U-Value
Total R-Value

$$\frac{1/0.026}{1+\text{Total U-Value}}$$

Reference Name: FX.30.2x10.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Size:
Framing Spacing:
Framing Percentage:
 (check one)

- Wood**
 2 × 8
 16 "o.c.
 Wall: _____ 15% (16"o.c.)
 _____ 12% (24"o.c.)
 _____ 9% (48"o.c.)
 Floor/Ceiling 10% (16"o.c.)
 _____ 7% (24"o.c.)
 _____ 4% (48"o.c.)
 NA

Wall Weight / sf:
(Packages only)

List of Construction Components

- Outside Surface Air Film
1. R-30 fiberglass insulation
 2. 9.25 in fir framing
 3. 0.625 in plywood
 4. Carpet & pad
 5. _____
 6. _____
 7. _____
- Inside Surface Air Film

Total Unadjusted R-Values:

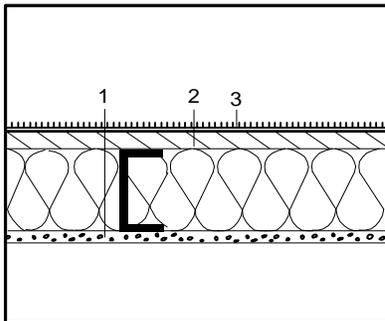
R-Value	
Cavity (R _c)	Frame (R _f)
0.170	0.170
30.000	-----
-----	9.158
0.770	0.770
2.080	2.080
-----	-----
-----	-----
0.920	0.920
39.940	19.098
R_c	R_f

Framing Adjustment Calculation:

$$\left[\frac{1}{1+R_c} \times \left(\frac{1-10/100}{1-(Fr.\% \div 100)} \right) \right] + \left[\frac{1}{1+R_f} \times \left(\frac{10/100}{Fr.\% \div 100} \right) \right] = \frac{1/0.034}{1+\text{Total U-Value}}$$

0.034
Total U-Value
 = **29.412**
Total R-Value

Reference Name: FX.30.2x10.16



Sketch of Construction Assembly

Assembly Type:
(check one)

- Floor
 Wall
 Ceiling/Roof

Framing Material:
Framing Spacing:
Framing Size:

- Metal**
 16 "o.c.
 Actual Depth 10.000
 Actual Width 1.625
 R-value 38.000
 Knock-out (%) 15.000
 Web Thickness 0.060
 Interior Flange _____
 Exterior Flange _____

Cavity Insulation:

Insulation Tape R-value:

List of Construction Components

- Outside Surface Air Film
1. 2.50 in polyisocyanurate
 2. 0.625 in plywood
 3. Carpet & pad
 4. _____
 5. _____
 6. _____
 7. _____
- Inside Surface Air Film

R-Value

0.170
17.50
0.780
2.080

0.920

Calculation:

From EZFRAME

0.031
Total U-Value

$$\frac{1/0.031}{1+\text{Total U-Value}}$$

32.110
Total R-Value

Computer Modeling of Framed Assemblies

EZFrame can be purchased by ordering the following:

Publication No.:	P400-94-002R
Cost:	\$14.00
Address:	California Energy Commission Publications, MS-13 P.O. Box 944295 Sacramento, CA 94244-2950

TABLE B-8B: Fan Motor Efficiencies (1 HP and over)

Number of Poles Synchronous Speed	Open Motors				Enclosed Motors			
	2 3600	4 1800	6 1200	8 900	2 3600	4 1800	6 1200	8 900
Motor Horsepower								
1	—	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	92.0	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.0	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	—	95.4	95.4	95.0	—
350	95.0	95.4	95.4	—	95.4	95.4	95.0	—
400	95.4	95.4	—	—	95.4	95.4	—	—
450	95.8	95.8	—	—	95.4	95.4	—	—
500	95.8	95.8	—	—	95.4	95.8	—	—

Table B-9: Minimum Mechanical Equipment Efficiencies

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard	
Gas Fan Type Central Furnaces	< 225 kBtu/hr		78% AFUE	Note (3)	
	> or = 225 kBtu/hr	max. cap. (1)	80% thermal	ANSI Z21.47-83	
Oil Furnaces/AC Units	> or = 225 kBtu/hr	min. rated cap. (1)	78% thermal	ANSI Z21.47-83	
		both max. and min. rated cap. (1)	81% thermal	U.L. 727-86	
Gas Wall Furnaces				Note (4)	
fan type	< or = 42 kBtu/hr		73% AFUE		
	> 42 kBtu/hr		74% AFUE		
gravity type	< or = 10 kBtu/hr		59% AFUE		
	10 kBtu/hr but < or = 12 kBtu/hr		60% AFUE		
	12 kBtu/hr but < or = 15 kBtu/hr		61% AFUE		
	15 kBtu/hr but < or = 19 kBtu/hr		62% AFUE		
	19 kBtu/hr but < or = 27 kBtu/hr		63% AFUE		
	27 kBtu/hr but < or = 46 kBtu/hr		64% AFUE		
	> 46 kBtu/hr		65% AFUE		
	Gas Floor Furnaces	< or = 37 kBtu/hr		56% AFUE	Note (4)
		> 37 kBtu/hr		57% AFUE	
	Gas Room Furnaces	< or = 18 kBtu/hr		57% AFUE	Note (4)
18 kBtu/hr but < or = 20 kBtu/hr			58% AFUE		
20 kBtu/hr but < or = 27 kBtu/hr			63% AFUE		
27 kBtu/hr but < or = 46 kBtu/hr			64% AFUE		
> 46 kBtu/hr			65% AFUE		
Gas Duct Furnaces			max. rated cap. (1)	80% thermal	ANSI Z83.9-1986
		min. rated cap. (1)	75% thermal		
		standby	10 watts		
Gas Unit Heaters	gas-fired		LPG standby	147 watts	
			max. rated cap. (1)	80% thermal	ANSI Z83.8-1990
			min. rated cap. (1)	74% thermal	
		standby	10 watts		
oil-fired	all sizes	LPG standby (2)	147 watts		
		max. & min. rated cap. (1)	81% thermal	UL 731-88	

Notes to Table:

1. Provided and allowed by the controls.
2. For units designed expressly for use with liquefied petroleum gases.
3. 10 Code of Federal Regulations Section 430.22 (n) 1989.
4. 10 Code of Federal Regulations Section 430.22 (o) 1989.

(Compiled from Appliance Efficiency and California Building Standards, Titles 20 and 24).

**Table B-9: Minimum Mechanical Equipment Efficiencies
(Continued)**

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Air Conditioners				
Packaged terminal air conditioners				ARI 310-87
	Standard rating	95 deg.	Note (2)	
	Low temperature rating	82 deg.	Note (3)	
Packaged terminal heat pumps				ARI-380-87
	Standard cooling	95 deg.	Note (2)	
	Low temperature cooling	82 deg.	Note (3)	
	Heating	47 deg. db/43 deg. wb	Note (4)	
All Other Room Air Conditioners				Note (1)
	Without reverse cycle/ with louvered sides	<6,000 Btu/hr	8.0 EER	
		6,000 - 7,999 Btu/hr	8.5 EER	
		8,000 - 13,999 Btu/hr	9.0 EER	
		14,000 - 19,999 Btu/hr	8.8 EER	
		>or= 20,000 Btu/hr	8.2 EER	
	Without reverse cycle/ without louvered sides	<6,000 Btu/hr	8.0 EER	
		>or= 6,000 but <20,000 Btu/hr	8.5 EER	
		>or= 20,000 Btu/hr	8.2 EER	
	With reverse cycle/ with louvered sides		8.5 EER	
	With reverse cycle/ without louvered sides		8.0 EER	
Computer Room Air Conditioners				ANSI/ASHRAE 127-1988
	Air Cooled	< 65 kBtu/hr	8.3 EER	
		>or= 65 < 135 kBtu/hr	7.7 EER	
	Water Cooled	< 65 kBtu/hr	8.1 EER	
		>or= 65 < 135 kBtu/hr	8.4 EER	

Notes to Table:

- 10 CFR Section 430.33(f) (1995).
- At Standard Rating of 95 deg. F drybulb: $EER = 10.0 - (.16 \times Cap/1000)$. where Cap = rated cooling capacity.
If the unit's capacity is less than 7000 Btu/hr, use 7000 Btu/h in the calculation.
If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/hr
- At Low Temperature Rating of 82 deg. drybulb: $EER = 12.2 - (.20 \times Cap/1000)$. If the unit's capacity is less than 7,000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit's capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculation. For multi-capacity equipment, the minimum performance shall apply to each capacity step provided and allowed by the controls.
- At Standard Rating of 47 deg. F drybulb 43 deg. wetbulb: $COP = 1.3 + 0.16(EER_{95} \text{ per Note 2})$.

**Table B-9: Minimum Mechanical Equipment Efficiencies
(Continued)**

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Central Air Conditioning Heat Pumps				
Air-Source Heat Pumps				
Split system	cooling	<65 kBtu/hr	10.0 SEER	ARI 240-81
	heating		6.8 HSPF	
Single package	cooling		9.7 SEER	
	heating		6.6 HSPF	
All	Cooling	>or= 65, <135 kBtu/hr	8.9 EER	ARI 240-81
	Heating		47°F db/43 wb 17°F db/15 wb	
All	Cooling	>or= 135 kBtu/hr <760 kBtu/hr	8.5 EER	ARI 340-86
	Heating		47°F 17°F	
All	Cooling	>or= 760 kBtu/hr	8.2 EER	
	Heating		47°F 17°F	
Water Source Heat Pumps				ARI 320-86
Cooling (1)		< 65 kBtu/hr	85 deg. Water (3)	10.0 EER
			75 deg. Water (3)	10.2 EER
heating (2)		>or= 65, <135 kBtu/hr	85 deg. water (3)	10.5 EER
			70 deg. water (3)	3.8 COP
Ground Water Heat Pumps				ARI 325-85
cooling (1)			70 deg. water (3)	11.0 EER
			50 deg. water (3)	11.5 EER
heating (2)			70 deg. water (3)	3.5 COP
			50 deg. water (3)	3.0 COP

**Table B-9: Minimum Mechanical Equipment Efficiencies
(Continued)**

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Air-Cooled Central Air Conditioners				ARI 210-81
Split system	< 65 kBtu/hr		10.0 SEER	
Single package			9.7 SEER	
All	>or= 65, < 135 kBtu/hr	95 °F db 80 °F db	8.9 EER 8.3 IPLV	
All	>or= 135, <760 kBtu/hr		8.5 EER 7.5 IPLV	ARI 360-86
All	>or= 760 kBtu/hr		8.2 EER 7.5 IPLV	ARI 360-86
Evaporatively-Cooled Central Air Conditioners				
	< 65 kBtu/hr	95 °F db/ 75 °F wb (1) 80 °F db/ 67 °F wb (1)	9.3 EER 8.5 IPLV	
	> or = 65, < 135 kBtu/hr	95 °F db/ 75 °F wb (1) 80 °F db/ 67 °F wb (1)	10.5 EER 9.7 IPLV	
	> or = 135 kBtu/hr		9.6 EER 9.0 IPLV	ARI 360-86 CTI 201(86)
Water-Cooled Central Air Conditioners				
	<65 kBtu/hr	85 °F (2) 75 °F (2)	9.3 EER 8.3 IPLV	
	> or = 65, < 135 kBtu/hr	85 °F (2)	10.5 EER	
	> or = 135 kBtu/hr		9.6 EER 9.0 IPLV	ARI 360-86 CTI 201(86)
Condensing Units				
Air Cooled	> or = 135 kBtu/hr		9.9 EER 11.0 IPLV	ARI 365-87
Water or Evap. Cooled	> or = 135 kBtu/hr		12.9 EER 12.9 IPLV	ARI 365-87 CTI 201 (86)

Notes to Table:

1. Outdoor condition, dry bulb and wet bulb
2. Entering water temperature.

**Table B-9: Minimum Mechanical Equipment Efficiencies
(Continued)**

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Electric Water Chilling Packages				
Water Cooled	< 150 tons		3.8 COP	CTI 201 (86)
			3.9 IPLV	ARI 550-90 ARI 590-90
	> or = 150 tons but <300 tons		4.2 COP	
			4.5 IPLV	
	> or = 300 tons	Note 1	5.2 COP	
			5.3 IPLV	
	all others	4.7 COP		
			4.8 IPLV	
Air cooled, with condenser	< 150 tons		2.7 COP	ARI 550-90
			2.8 IPLV	ARI 590-90
	> or = 150 tons		2.5 COP	
			2.5 IPLV	
Air cooled, without condenser	All sizes		3.1 COP	ARI 550-90
			3.2 IPLV	ARI 590-90

Notes to Table:

1. With CFC refrigerants with ozone depletion factors greater than those for R-22.

**Table B-9: Minimum Mechanical Equipment Efficiencies
(Continued)**

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Gas Boilers				
Steam Boilers	< 300 kBtu/hr		75% AFUE	10 CFR Section 430.22 (n) (1995)
Other Boilers	< 300 kBtu/hr		80% AFUE	430.22 (n) (1995)
All	>or= 300 kBtu/hr	at both max & min capacity (1)	80% Thermal	ANSI Z21.13-1987
		standby LPG other gases	352 watts (2) 147 watts	
Oil Boilers - All fuels				
	<300 kBtu/hr		80% AFUE	10 CFR Part 430, Appendix N
Other than Residual Oil	>or= 300 kBtu/hr	at both max & min capacity (1)	83% Combustion	HI Heating Boiler Standard 86 ASME PTC 4.1-64 UL 726-75
Residual oil	>or= 300 kBtu/hr	at both max & min capacity (1)	83% Combustion	HI Heating Boiler Standard 86 ASME PTC 4.1-64

Notes to Table:

1. Provided and allowed by the controls.
2. For boilers designed expressly for use with liquefied petroleum gases.

**Table B-9: Minimum Mechanical Equipment Efficiencies
(Continued)**

Type	Fuel	Input Rating	Volume (gallons)	Input to Vol. Ratio (Btuh/gal)	Thermal Eff. (%)	Standby Loss ⁽¹⁾ (%/hr)	Energy Factor ⁽²⁾
Service Water Heaters							
Storage	Gas	<or = 75,000 Btu/hr	>or = 20				0.62 - (0.0019 x V)
Storage	Gas	> 75,000 Btu/hr <or = 155,000 Btu/hr	All	< 4,000	78%	1.3 + 114/V	
Storage	Gas	> 155,000 Btu/hr	All	< 4,000	78%	1.3 + 95/V	
Storage	Gas	> 155,000 Btu/hr	>or = 10	>or = 4,000	77%	2.3 + 67/V	
Instantaneous	Gas	<or = 200,000 Btu/hr					0.62 - (0.0019 x V)
Instantaneous	Gas	> 200,000 Btu/hr	< 10	>or = 4,000	80%	no requirement	
Instantaneous	Gas	> 200,000 Btu/hr	>or = 10	>or = 4,000	77%	2.3 + 67/V	
All	Electric	<or = 12 kW	>or = 20				0.93 - (0.00132 x V)
Storage	Electric	> 12 kW				0.30 + 27/V	
Storage	Oil	<or = 105,000 Btu/hr	>or = 20				0.59 - (0.0019 X V)
Storage	Oil	105,000 Btu/hr 155,000 Btu/hr		<4,000	78%	1.3 + 114/V	
Storage	Oil	>155,000 Btu/hr		< 4,000	78%	1.3 + 95/V	
Instantaneous	Oil	<or = 210,000 Btu/hr					0.59 - (0.0019 X V)
Instantaneous	Oil	> 210,000 Btu/hr	< 10	>or = 4,000	80%	no requirement	
Instantaneous	Oil	> 210,000 Btu/hr	>or = 10	>or = 4,000	77%	2.3 + 67/V	

(1) V in the Standby Loss equations is "measured" volume.

(2) V in the Energy Factor equations is the "rated" volume.

Table B-10: Illuminance Categories

NOTE: This table is taken from the *Office Lighting American National Standard Practice*, ANSI/IES RP-1, 1993. The table is produced in its entirety, including captions and footnotes. Permission to reprint is pending.

TABLE 3: Currently recommended illuminance categories for lighting design --target maintained values (See Table 4 for Illuminance Values). These recommendations provide a guide for efficient visual performance in office spaces rather than for safety alone. For a tabulation of minimum levels of illumination required for safety, see Table 7.

	Illuminance Category	Veiling Reflectance

Accounting (see individual tasks)		
Copied Tasks		
Ditto Copy (6)	E	!
Micro-fiche reader (1)	B	!!
Mimeograph	D	
Photographs, mod. detail	E	!!
Thermal copy, poor copy	F	!
Xerography, 3rd generation (6) and greater	E	
Xerograph	D	
Drafting Tasks		
Drafting: Mylar		
High contrast media; India ink, plastic leads, soft graphite leads	E	!
Low contrast media, hard graphite leads	F	!
Vellum: high contrast	E	!
low contrast	F	
Tracing paper: high contrast	E	!
low contrast	F	
Overlays (2)		
Light Table	C	
Prints: Blue Line	E	
Blueprints	E	
Sepia prints	F	

TABLE 3 (continued)	Illuminance Category	Veiling Reflectance

EDP Tasks		
CRT Screens (1)	B	!!
Impact printer: good ribbon	D	
poor ribbon (6)	E	
2nd carbon and greater (6)	E	
Ink jet printer	D	
Keyboard reading	D	
Machine rooms: active operations	D	
tape storage	D	
machine area	C	
equipement service (3)	E	
Thermal print	E	!
Filing		
(see individual tasks)		
General and Public Areas		
AV areas	D	
Conference rooms	D	
(critical seeing, refer to individual tasks)		
Display areas (4)	C	
Duplicating and off-set printing area	D	
Elevators	C	
Escalators	C	
First aid areas	E	
Food service (7)		
Hallways	B	
Janitorial spaces	C	
Libraries (7)		
Lobbies and lounges	C	
Model making	F	
Mail sorting	E	
Mechanical rooms: operation	B	
equipment service (3)	E	
Reception area	C	
Rest rooms	C	
Stairs	B	
Utility rooms	B	
Graphic Design and Material		
Color selection (5)	F	
Charting and mapping	F	
Graphs	E	
Keylining	F	
Layout and artwork	F	
Photographs, mod. detail	E	!!
Handwritten Tasks		
#2 pencil and softer leads	D	!
#3 pencil	E	!
#4 pencil and harder leads (6)	F	!
Ball-point pen	D	!
Felt-tip pen	D	
Handwritten carbon copies (6)	E	
Non photographically reproducible colors	F	

TABLE 3 (continued)	Illuminance Category	Veiling Reflectance
Printed Tasks		
6 pt (6) see 2.4	E	!
8 & 10 pt	D	!
Glossy magazines	D	!!
Maps	E	
Newsprint	D	
Typed Originals	D	
Typed 2nd carbon and later (6)	E	
Telephone books	E	

NOTES:

1. Veiling reflections may be produced on glass surfaces. It may be necessary to treat plus weighting factors as minus in order to obtain proper light balance.
 2. Degradation factors: Overlays--add 1 weighing factor for each overlay
Used material--estimate additional factors
See Table 4
 3. Only when actual equipment service is in progress. May be achieved by a general lighting system or by localized lighting or by portable equipment.
 4. For details on the lighting of display refer to Recommended Practice for Lighting Merchandise Areas. (10)
 5. For color matching, the quality of the color of the light source may be important.
 6. Designing to higher levels to accommodate poor quality tasks should be undertaken only after it is determined that task quality cannot be improved. If a poor quality task cannot be eliminated, its "time-and-importance" factor should be carefully considered before allowing it to govern the illuminance level selection.
 7. See Reference 9.
- ! Task subject to veiling reflections. Illuminance listed is not an ESI value. Currently, insufficient experience in the use of ESI target values precludes the direct use of Equivalent Sphere Illumination in the present consensus approach recommend illuminance values. Equivalent Sphere Illumination may be used as a tool in determining the effectiveness of controlling veiling reflections and as part of the evaluation of lighting systems.
- !! Especially subject to veiling reflectances. It may be necessary to shield the task or to reorient it.

Definition of Merchandising and Associated Service Areas in Stores

NOTE: This table is taken from the *Recommended Practice for Lighting Merchandising Areas*, IES RP-2. The table is produced in its entirety, including captions and footnotes. Permission to reprint is pending.

TABLE 1 -- Currently Recommended Illuminance for Lighting Design in Merchandising and Associated Areas -- Target Maintained Levels

Areas or Tasks	Description	Type of Activity Area*	Lux	Foot-candles
Circulation	Area not used for display or appraisal of merchandise for sales transactions	High activity	300	30
		Medium activity	400	20
		Low activity	100	10
Merchandise*** (including showcases & wall displays)	That plane area, horizontal to vertical, where merchandise is displayed and readily accessible for customer examination	High activity	1000	100
		Medium activity	750	75
		Low activity	300	30

Show windows				
	Daytime lighting			
	General		2000	200
	Feature		10000	1000

Nighttime lighting				
	Main business districts- highly competitive			
	General		2000	200
	Feature		10000	1000

Secondary business districts or small towns				
	General		1000	100
	Feature		5000	500

Sales Transactions	Areas used for employee price verification and for recording transactions	Reading of copied, written, printed or EDP information		See Table 2

Support Services	Store spaces where merchandising is a prime consideration	Alteration fitting stock, wrapping and packaging rooms		See Table 2

NOTES:

- * One store may encompass all three types within the building: High Activity area -- where merchandise displayed has recognizable usage. Evaluation and viewing time is rapid, and merchandise is shown to attract and stimulate the impulse buying decision; Medium Activity -- where merchandise is familiar in type or usage, but the customer may require time and/or help in evaluation of quality, usage, or for the decision to buy; and Low Activity -- where merchandise is displayed that is purchased less frequently by the customer, who may be unfamiliar with the inherent quality, design, value or usage. Where assistance and time is necessary to reach a buying decision.
- ** Maintained on the task or in the area at any time.
- *** Lighting levels to be maintained in the plane of the merchandise.

Fig. 2-1. Currently Recommended Illuminance Categories and Illuminance Values for Lighting Design -- Targeted Maintenance Levels.

The tabulation that follows is a consolidated listing of the Society's current illuminance recommendations. This listing is intended to guide the lighting designer in selecting an appropriate illuminance for design and evaluation of lighting systems.

Guidance is provided in two forms: (1), in Parts I, II and III as an *Illuminance Category*, representing a range of illuminances (see page 2-3 for a method of selecting a value within each illuminance range); and (2), in parts IV, V and VI as an *Illuminance Value*. Illuminance Values are given in *lux* with an approximate equivalence in footcandles and as such are intended as *target* (nominal) values with deviations expected. These target values also represent maintained values (see page 2-23).

This table has been divided into the six parts for ease of use. Part I provides a listing of both Illuminance Categories and Illuminance Values for generic types of interior activities and normally is to be used when Illuminance Categories for a specific Area/Activity cannot be found in parts II and III. Parts IV, V and VI provide target maintained Illuminance Values for outdoor facilities sports and recreational areas, and transportation vehicles where special considerations apply as discussed on page 2-4.

In all cases the recommendations in this table are based on the assumption that the lighting will be properly designed to take into account the visual characteristics of the task. See the design information in the particular application sections in this Application Handbook for further recommendations.

II. Commercial, Institutional, Residential and Public Assembly Interiors			
Area/Activity	Illuminance Category	Area/Activity	Illuminance Category
Accounting (see Reading)		Court rooms	
Air terminals (see Transportation terminals)		Seating area	C
Armories	C ¹	Court activity area	E ³
Art galleries (see Museums)		Dance halls and discotheques	B
Auditoriums		Depots, terminals and stations	
Assembly	C ¹	(see Transportation terminals)	
Social activity	B	Drafting	
Banks		Mylar	
Lobby		High contrast media; India ink, plastic leads, soft graphite leads	E ³
General	C	Low contrast media; hard graphite leads	F ³
Writing area	D	Vellum	
Tellers' stations	E ³	High contrast	E ³
Barber shops and beauty parlors	E	Low contrast	F ³
Churches and synagogues	(see page 7-2) ⁴	Tracing paper	
Club and lodge rooms		High contrast	E ³
Lounge and reading	D	Low contrast	F ³
Conference rooms		Overlays ⁵	
Conferring	D	Light table	C
Critical seeing (refer to individual task)		Prints	
		Blue line	E
		Blueprints	E
		Sepia prints	F

NOTE: This table is taken from the Figure 2-2 of the IES Lighting Handbook 1982 Application Volume. Part II of the table is produced in its entirety, with captions and footnotes. Permission to reprint is pending.

Fig. 2-1. Continued

II. Continued

Area/Activity	Illuminance Category	Area/Activity	Illuminance Category
Educational facilities		Cardiac function lab	E
Classrooms		Central sterile supply	
General (see Reading)		Inspection, general	E
Drafting (see Drafting)		Inspection	F
Home economics (see Residences)		At sinks	E
Science laboratories	E	Work areas, general	D
Lecture rooms		Processed storage	D
Audience (see Reading)		Corridors ¹⁷	
Demonstration	F	Nursing areas -- day	C
Music rooms (see Reading)		Nursing areas -- night	B
Shops (see Part III, Industrial Group)		Operating areas, delivery, recovery, and laboratory suites and service	E
Sight saving rooms	F	Critical care areas ¹⁷	
Study halls (see Reading)		General	C
Typing (see Reading)		Examination	E
Sports facilities (see Part V, Sports and Recreational Areas)		Surgical task lighting	H
Cafeterias (see Food service facilities)		Hand washing	F
Dormitories (see Residences)		Cystoscopy room ^{17,18}	
Elevator, freight and passenger	C	Dental suite ¹⁷	
Exhibition halls	C ¹	General	D
Filing (refer to individual task)		Instrument tray	E
Financial facilities (see Banks)		Oral Cavity	H
Fire halls (see Municipal buildings)		Prosthetic laboratory, general	D
Food service facilities		Prosthetic laboratory, work bench	E
Dining areas		Prosthetic, laboratory, local	F
Cashier	D	Recovery room, general	C
Cleaning	C	Recovery room, emergency examination	E
Dining	B ⁶	Dialysis unit, medical ¹⁷	F
Food displays (see Merchandising spaces)		Elevators	C
Kitchen	E	EKG and specimen room ¹⁷	
Garages -- parking (see page 14-28)		General	B
Gasoline stations (see Service stations)		On equipment	C
Graphic design and material		Emergency outpatient ¹⁷	
Color selection	F ¹¹	General	E
Charting and mapping	F	Local	F
Graphs	E	Endoscopy rooms ^{17,18}	
Keylining	F	General	E
Layout and artwork	F	Peritoneoscopy	D
Photographs, moderate detail	E ¹³	Culdoscopy	D
Health care facilities		Examination and treatment rooms ¹⁷	
Ambulance (local)	E	General	D
Anesthetizing	E	Local	E
Autopsy and morgue ^{17,18}		Eye surgery ^{17,18}	F
Autopsy, general	E	Fracture room ¹⁷	
Autopsy table	G	General	E
Morgue, general	D	Local	F
Museum	E	Inhalation therapy	D
		Laboratories ¹⁷	
		Specimen collecting	E
		Tissue laboratories	F
		Microscopic reading room	D
		Gross specimen review	F
		Chemistry rooms	E

Fig. 2-1. Continued

II. Continued

Area/Activity	Illuminance Category	Area/Activity	Illuminance Category
Bacteriology rooms		Radiological suite ¹⁷	
General	E	Diagnostic section	
Reading culture plates	F	General ¹⁸	A
Hematology	E	Waiting area	A
Linens		Radiographic/fluoroscopic room	A
Sorting soiled linen	D	Film sorting	F
Central (clean) linen room	D	Barium kitchen	E
Sewing room, general	D	Radiation therapy section	
Sewing room, work area	E	General ¹⁸	B
Linen closet	B	Waiting area	B
Lobby	C	Isotope kitchen, general	E
Locker rooms	C	Isotope kitchen, benches	E
Medical illustration studio ^{17, 18}	F	Computerized radiotomography section	
Medical records	E	Scanning room	B
Nurseries ¹⁷		Equipment maintenance room	E
General ¹⁸	C	Solarium	
Observation and treatment	E	General	C
Nursing stations ¹⁷		Local for reading	D
General	D	Stairways	C
Desk	E	Surgical suite ¹⁷	
Corridors, day	C	Operating room, general ¹⁸	F
Corridors, night	A	Operating table	(see page 7-15)
Medication station	E	Scrub room	F
Obstetric delivery suite ¹⁷		Instruments and sterile supply room	D
Labor rooms		Clean up room, instruments	E
General	C	Anesthesia	C
Local	E	Substerilizing room	C
Birthing room	F	Surgical induction room ^{17, 18}	E
Delivery area		Surgical holding area ^{17, 18}	E
Scrub, general	F	Toilets	C
General	G	Utility room	D
Delivery table	(see page 7-19)	Waiting areas ¹⁷	
Resuscitation	G	General	C
Post delivery recovery area	E	Local for reading	D
Substerilizing room	B	Homes (see Residences)	
Occupational therapy ¹⁷		Hospitality facilities	
Work area, general	D	(see Hotels , food service facilities)	
Work tables or benches	E	Hospitals (see Health care facilities)	
Patients' rooms ¹⁷		Hotels	
General ¹⁸	B	Bathrooms, for grooming	D
Observation	A	Bedrooms, for reading	D
Critical examination	E	Corridors, elevators and stairs	C
Reading	D	Front desk	E ³
Toilets	D	Linen room	
Pharmacy ¹⁷		Sewing	F
General	E	General	C
Alcohol vault	D	Lobby	
Laminar flow bench	F	General lighting	C
Night light	A	Reading and working areas	D
Parenteral solution room	D	Canopy (see Part IV, Outdoor Facilities)	
Physical therapy departments		Houses of worship	(see page 7-5)
Gymnasiums	D	Kitchens (see Food service facilities or Residences)	
Tank rooms	D	Libraries	
Treatment cubicles	D	Reading areas (see Reading)	
Postanesthetic recovery room ¹⁷			
General ¹⁸	E		
Local	H		
Pulmonary function laboratories ¹⁷	E		

Fig. 2-1. Continued

II. Continued			
Area/Activity	Illuminance Category	Area/Activity	Illuminance Category
Book stacks [vertical 760 millimeters (30 inches) above floor]		Parking facilities	(see page 14-28)
Active stacks	D	Post offices (see Offices)	
Inactive stacks	B	Reading	
Book repair and binding	D	Copied tasks	
Cataloging	D ³	Ditto copy	E ³
Card files	E	Micro-fiche reader	B ^{12, 13}
Carrels, individual study areas (see Reading)	D	Mimeograph	D
Map, picture and print rooms (see Graphic design and material)		Photograph, moderate detail	E ¹³
Audiovisual areas	D	Thermal copy, poor copy	F ³
Audio listening areas	D	Xerography	D
Microform areas (see Reading)		Xerography, 3rd generation and greater	E
Locker rooms	C	Electronic data processing tasks	
Merchandising spaces		CRT screens	B ^{12, 13}
Alteration room	F	Impact printer	
Fitting room		good ribbon	D
Dressing areas	D	poor ribbon	E
Fitting areas	F	2nd carbon and greater	E
Locker rooms	C	Ink jet printer	D
Stock rooms, wrapping and packaging	D	Keyboard reading	D
Sales transaction area (see Reading)		Machine rooms	
Circulating	(see page 8-7) ⁸	Active operations	D
Merchandise	(see page 8-7) ⁸	Tape storage	D
Feature display	(see page 8-7) ⁸	Machine area	C
Show windows	(see page 8-7) ⁸	Equipment service	E ¹⁰
Motels (see Hotels)		Thermal print	E
Municipal buildings -- fire and police		Handwritten tasks	
Police		#2 pencil and softer leads	D ³
Identification records	F	#3 pencil	E ³
Jail cells and interrogation rooms	D	#4 pencil and harder leads	F ³
Fire hall	D	Ball-point pen	D ³
Museums		Felt-tip pen	D
Displays of non-sensitive materials	D	Handwritten carbon copies	E
Displays of sensitive materials	(see page 7-34) ²	Non photographically reproducible colors	F
Lobbies, general gallery areas, corridors	C	Chalkboards	E ³
Restoration or conservation shops and laboratories	E	Printed tasks	
Nursing homes (see Health care facilities)		6 point type	E ³
Offices		8 and 10 point type	D ³
Accounting (see Reading)		Glossy magazines	D ¹³
Audio-visual areas	D	Maps	E
Conference areas (see Conference rooms)		Newsprint	D
Drafting (see Drafting)		Typed originals	D
General and private offices (see Reading)		Typed 2nd carbon and later	E
Libraries (see Libraries)		Telephone books	E
Lobbies, lounges and reception areas	C	Residences	
Mail sorting	E	General lighting	
Off-set printing and duplicating area	D	Conversation, relaxation and entertainment	B
Spaces with VDTs	(see page 5-13)	Passage areas	B
		Specific visual tasks ²⁰	
		Dining	C
		Grooming	
		Makeup and shaving	D
		Full-length mirror	D

Fig. 2-1. Continued

II. Continued			
Area/Activity	Illuminance Category	Area/Activity	Illuminance Category
Handcrafts and hobbies		Restaurants (see Food service facilities)	
Workbench hobbies			
Ordinary tasks	D	Safety	(see page 2-45)
Difficult tasks	E		
Critical tasks	F	Schools (see Educational facilities)	
Easel hobbies	E		
Ironing	D	Service spaces (see also Storage rooms)	
Kitchen duties		Stairways, corridors	C
Kitchen counter		Elevators, freight and passenger	C
Critical seeing	E	Toilet and washroom	C
Noncritical	D		
Kitchen range		Service stations	
Difficult seeing	E	Service bays (see Part III, Industrial Group)	
Noncritical	D	Sales room (see Merchandising spaces)	
Kitchen sink			
Difficult seeing	E	Show windows	(see page 8-7)
Noncritical	D		
Laundry		Stairways (see Service spaces)	
Preparation and tubs	D		
Washer and dryer	D	Storage rooms (see Part III, Industrial Group)	
Music study (piano or organ)			
Simple scores	D	Stores (see Merchandising spaces and Show windows)	
Advanced scores	E		
Substandard size scores	F	Television	(see Section 11)
Reading		Theater and motion picture houses	(see Section 11)
In a chair			
Books, magazines and newspapers	D	Toilets and washrooms	C
Handwriting, reproductions and poor copies	E		
In bed		Transportation terminals	
Normal	D	Waiting room and lounge	C
Prolonged serious or critical	E	Ticket counters	E
Desk		Baggage checking	D
Primary task plane, casual	D	Rest rooms	C
Primary task plane, study	E	Concourse	B
Sewing		Boarding area	C
Hand sewing			
Dark fabrics, low contrast	F		
Light to medium fabrics	E		
Occasional, high contrast	D		
Machine sewing			
Dark fabrics, low contrast	F		
Light to medium fabrics	E		
Occasional, high contrast	D		
Table games	D		

For footnotes, see following page

¹Include provisions for higher levels for exhibitions.

²Specific limits are provided to minimize deterioration effects.

³Task subject to veiling reflections. Illuminance listed is not an Equivalent Sphere Illumination (ESI) value. Currently, insufficient experience in the use of ESI target values precludes the direct use of ESI in the present consensus approach to recommend illuminance values. ESI may be used as a tool in determining the effectiveness of controlling veiling reflections and as a part of the evaluation of lighting systems.

⁴Illuminance values are listed based on experience and consensus. Values relate to needs during various religious ceremonies.

⁵Degradation factors: Overlays -- add 2 weighting factor for each overlay; Used material -- estimate additional factors.

⁶Provide higher level over food service or selection areas.

⁷Supplementary illumination as in delivery room must be available.

⁸Illuminance values developed for various degrees of store area activity.

⁹Or not less than 1/5 the level in the adjacent areas.

¹⁰Only when actual equipment service is in process. May be achieved by a general lighting system or by localized or portable equipment.

¹¹For color matching, the spectral quality of the color of the light source is important.

¹²Veiling reflections may be produced on glass surfaces. It may be necessary to treat plus weighting factors as minus in order to obtain proper illuminance.

¹³Especially subject to veiling reflections. It may be necessary to shield the task or to reorient it.

¹⁴Vertical

¹⁵Illuminance values may vary widely, depending upon the effect desired, the decorative scheme, and the use made of the room.

¹⁶Supplementary lighting should be provided in this space to produce the higher levels required for specific seeing tasks involved.

¹⁷Good to high color rendering capability should be considered in these areas. As lamps of higher luminous efficacy and higher color rendering capability become available and economically feasible, they should be applied in all areas of health care facilities.

¹⁸Variable (dimming or switching).

¹⁹Values based on a 25 percent reflectance, which is average for vegetation and typical outdoor surfaces. These figures must be adjusted to specific reflectances of materials lighted for equivalent brightness. Levels give satisfactory brightness patterns when viewed from dimly lighted terraces or interiors. When viewed from dark areas they may be reduced by at least 1/2; or they may be doubled when a high key is desired.

²⁰General lighting should not be less than 1/3 of visual task illuminance nor less than 200 lux [20 footcandles].

²¹Industry representatives have established a table of single illuminance values which, in their opinion, can be used in preference to employing reference 6. Illuminance values for specific operations can also be determined using illuminance categories of similar tasks and activities found in this table and the application of the appropriate weighting factors in Fig. 2-3.

²²Special lighting such that (1) the luminous area is large enough to cover the surface which is being inspected and (2) the luminance is within the limits necessary to obtain comfortable contrast conditions. This involves the use of sources of large area and relatively low luminance in which the source luminance is the principal factor rather than the illuminance produced at a given point.

²³Maximum levels -- controlled system.

²⁴Additional lighting needs to be provided for maintenance only.

²⁵Color temperature of the light source is important for color matching.

²⁶Select upper level for high speed conveyor systems. For grading redwood lumber 3000 lux [300 footcandles] is required.

²⁷Higher levels from local lighting may be required for manually operated cutting machines.

²⁸If color matching is critical, use illuminance category G.

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Power	Comments
No.	Designation	No.	Abbrev.	Description		
Fluorescent Circline						
Fluorescent Circline, Rapid Start (22 W)						
1	FC8T9	1	MAG STD	Magnetic Standard	27	8" OD
Fluorescent Circline, Rapid Start (32 W)						
1	FC12T9	1	MAG STD	Magnetic Standard	45	12" OD
Fluorescent Circline, Rapid Start (40 W)						
1	FC16T9	1	MAG STD	Magnetic Standard	57	16" OD
Fluorescent 2D						
Compact Fluorescent 2D (10W, GR10q-4 Four Pin Base)						
1	CFS10W/GR10q	1	MAG STD	Magnetic Standard	16	3.6" across
1	CFS10W/GR10q	1	ELECT	Electronic	13	
2	CFS10W/GR10q	1	ELECT	Electronic	26	
Compact Fluorescent 2D (16W, GR10q-4 Four Pin Base)						
1	CFS16W/GR10q	1	MAG STD	Magnetic Standard	23	5.5" across
1	CFS16W/GR10q	1	ELECT	Electronic	15	
2	CFS16W/GR10q	1	ELECT	Electronic	30	
Compact Fluorescent 2D (21W, GR10q-4 Four Pin Base)						
1	CFS21W/GR10q	1	MAG STD	Magnetic Standard	31	5.5" across
1	CFS21W/GR10q	1	ELECT	Electronic	21	
2	CFS21W/GR10q	1	ELECT	Electronic	42	
Compact Fluorescent 2D (28W, GR10q-4 Four Pin Base)						
1	CFS28W/GR10q	1	MAG STD	Magnetic Standard	38	8.1" across
1	CFS28W/GR10q	1	ELECT	Electronic	28	
2	CFS28W/GR10q	1	ELECT	Electronic	56	
Compact Fluorescent 2D (38W, GR10q-4 Four Pin Base)						
1	CFS38W/GR10q	1	ELECT	Electronic	37	8.1" across
2	CFS38W/GR10q	1	ELECT	Electronic	74	
Compact Fluorescent Twin (5 W, G23 Two Pin Base - F5TT Lamp)						
1	CFT5W/G23	1	MAG STD	Magnetic Standard	9	4.1" MOL
2	CFT5W/G23	2	MAG STD	Magnetic Standard	18	
Compact Fluorescent Twin (7 W, G23 Two Pin Base - F7TT Lamp)						
1	CFT7W/G23	1	MAG STD	Magnetic Standard	11	5.3" MOL
2	CFT7W/G23	2	MAG STD	Magnetic Standard	22	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Power	Comments
No.	Designation	No.	Abbrev.	Description		
Compact Fluorescent Twin (9 W, G23 Two Pin Base - F9TT Lamp)						
1	CFT9W/G23	1	MAG STD	Magnetic Standard	13	6.5" MOL
2	CFT9W/G23	2	MAG STD	Magnetic Standard	26	
Compact Fluorescent Twin (13 W, GX23 Two Pin Base - F13TT)						
1	CFT13W/GX23	1	MAG STD	Magnetic Standard	17	7.5" MOL
2	CFT13W/GX23	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (9 W, G23-2 Two Pin Base - F9DTT Lamp)						
1	CFQ9W/G23-2	1	MAG STD 120	120 V Magnetic Standard	13	4.4" MOL
2	CFQ9W/G23-2	2	MAG STD 120	120 V Magnetic Standard	26	
Compact Fluorescent Quad (13 W, G24d-1 Two Pin Base - F13DTT Lamp)						
1	CFQ13W/G24d-1	1	MAG STD 120	120 V Magnetic Standard	18	6.0" MOL
2	CFQ13W/G24d-1	2	MAG STD 120	120 V Magnetic Standard	36	
1	CFQ13W/G24d-1	1	MAG STD 277	227 V Magnetic Standard	16	
2	CFQ13W/G24d-1	2	MAG STD 277	227 V Magnetic Standard	32	
Compact Fluorescent Quad (13 W, GX23-2 Two Pin Base)						
1	CFQ13W/GX23-2	1	MAG STD	Magnetic Standard	17	4.8" MOL
2	CFQ13W/GX23-2	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (16W GX32d-1 Two Pin Base)						
1	CFQ16W/GX32d-1	1	MAG STD	Magnetic Standard	20	5.5" MOL
2	CFQ16W/GX32d-1	2	MAG STD	Magnetic Standard	40	
Compact Fluorescent Quad (18 W, G24d-2 Two Pin Base - F18DTT Lamp)						
1	CFQ18W/G24d-2	1	MAG STD 120	120 V Magnetic Standard	25	6.8" MOL
2	CFQ18W/G24d-2	2	MAG STD 120	120 V Magnetic Standard	50	
1	CFQ18W/G24d-2	1	MAG STD 277	227 V Magnetic Standard	22	
2	CFQ18W/G24d-2	2	MAG STD 277	227 V Magnetic Standard	44	
Compact Fluorescent Quad (22W, GX32d Two Pin Base)						
1	CFQ22W/GX32d-2	1	MAG STD	Magnetic Standard	27	6.0" MOL
2	CFQ22W/GX32d-2	2	MAG STD	Magnetic Standard	54	
Compact Fluorescent Quad (26 W, G24d-3 Two Pin Base - F26DTT Lamp)						
1	CFQ26W/G24d-3	1	MAG STD 120	120 V Magnetic Standard	37	7.6" MOL
2	CFQ26W/G24d-3	2	MAG STD 120	120 V Magnetic Standard	74	
1	CFQ26W/G24d-3	1	MAG STD 277	227 V Magnetic Standard	33	
2	CFQ26W/G24d-3	2	MAG STD 277	227 V Magnetic Standard	66	
1	CFQ26W/G24d-3	1	ELECT 277V	277 V Electronic	27	
2	CFQ26W/G24d-3	2	ELECT 277V	277 V Electronic	54	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Compact Fluorescent Quad (28W GX32d Two Pin Base)						
1	CFQ28W/GX32d-3	1	MAG STD	Magnetic Standard	34	6.8" MOL
2	CFQ28W/GX32d-3	2	MAG STD	Magnetic Standard	68	
Compact Fluorescent Quad (10 W, G24q-1 Four Pin Base)						
1	CFQ10W/G24q-1	1	MAG STD 120	120 V Magnetic Standard	16	4.6" MOL
2	CFQ10W/G24q-1	2	MAG STD 120	120 V Magnetic Standard	32	
1	CFQ10W/G24q-1	1	MAG STD 277	227 V Magnetic Standard	13	
2	CFQ10W/G24q-1	2	MAG STD 277	227 V Magnetic Standard	26	
Compact Fluorescent Quad (13 W, G24q-1 Four Pin Base)						
1	CFQ13W/G24q-1	1	MAG STD 120	120 V Magnetic Standard	18	6.0" MOL
2	CFQ13W/G24q-1	2	MAG STD 120	120 V Magnetic Standard	36	
1	CFQ13W/G24q-1	1	MAG STD 277	227 V Magnetic Standard	16	
2	CFQ13W/G24q-1	2	MAG STD 277	227 V Magnetic Standard	32	
Compact Fluorescent Quad (13 W, GX7 Four Pin Base)						
1	CFQ13W/GX7	1	MAG STD	Magnetic Standard	17	4.8" MOL
2	CFQ13W/GX7	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (18 W, G24q-2 Four Pin Base)						
1	CFQ18W/G24q-2	1	MAG STD 120	120 V Magnetic Standard	25	6.8" MOL
2	CFQ18W/G24q-2	2	MAG STD 120	120 V Magnetic Standard	50	
1	CFQ18W/G24q-2	1	MAG STD 277	227 V Magnetic Standard	22	
2	CFQ18W/G24q-2	2	MAG STD 277	227 V Magnetic Standard	44	
Compact Fluorescent Triple (13 W, GX24q-1 Four Pin Base)						
1	CFM 13W/GX24q-1	1	MAG STD	Magnetic Standard	18	4.2" MOL
2	CFM 13W/GX24q-1	2	MAG STD	Magnetic Standard	36	
Compact Fluorescent Triple (18W, GX24q-2 Four Pin Base)						
1	CFM 18W/GX24q-2	1	MAG STD	Magnetic Standard	25	5.0" MOL
2	CFM 18W/GX24q-2	2	MAG STD	Magnetic Standard	50	
Compact Fluorescent Triple (26W, GX24q-3 Four Pin Base)						
1	CFM 26W/GX24q-3	1	MAG STD	Magnetic Standard	37	4.9 to 5.4" MOL
2	CFM 26W/GX24q-3	2	MAG STD	Magnetic Standard	74	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Fluorescent Twin (18W - F18TT Lamp)						
1	FT18W/2G11	1	MAG EE	Magnetic Energy Efficient	23	
2	FT18W/2G11	1	MAG EE	Magnetic Energy Efficient	46	
3	FT18W/2G11	1.5	MAG EE	Magnetic Energy Efficient	69	Tandem wired
3	FT18W/2G11	2	MAG EE	Magnetic Energy Efficient	69	
4	FT18W/2G11	2	MAG EE	Magnetic Energy Efficient	92	(2) Two-lamp ballasts
1	FT18W/2G11	1	ELECT	Electronic	17	
2	FT18W/2G11	1	ELECT	Electronic	35	
3	FT18W/2G11	1.5	ELECT	Electronic	52	Tandem wired
3	FT18W/2G11	2	ELECT	Electronic	52	
4	FT18W/2G11	2	ELECT	Electronic	70	(2) Two-lamp ballasts
Fluorescent Twin (24-27W- F24TT or F27TT Lamp)						
1	FT24W/2G11	1	MAG EE	Magnetic Energy Efficient	32	
2	FT24W/2G11	1	MAG EE	Magnetic Energy Efficient	66	
3	FT24W/2G11	1.5	MAG EE	Magnetic Energy Efficient	99	Tandem wired
3	FT24W/2G11	2	MAG EE	Magnetic Energy Efficient	98	
4	FT24W/2G11	2	MAG EE	Magnetic Energy Efficient	132	(2) Two-lamp ballasts
1	FT24W/2G11	1	ELECT	Electronic	21	
2	FT24W/2G11	1	ELECT	Electronic	43	
3	FT24W/2G11	1.5	ELECT	Electronic	64	Tandem wired
3	FT24W/2G11	2	ELECT	Electronic	64	
4	FT24W/2G11	2	ELECT	Electronic	86	(2) Two-lamp ballasts
Fluorescent Twin (36-39W - F36TT or F39TT Lamp)						
1	FT36W/2G11	1	MAG EE	Magnetic Energy Efficient	51	
2	FT36W/2G11	1	MAG EE	Magnetic Energy Efficient	66	
3	FT36W/2G11	1.5	MAG EE	Magnetic Energy Efficient	99	Tandem wired
3	FT36W/2G11	2	MAG EE	Magnetic Energy Efficient	117	
4	FT36W/2G11	2	MAG EE	Magnetic Energy Efficient	132	(2) Two-lamp ballasts
1	FT36W/2G11	1	ELECT	Electronic	37	
2	FT36W/2G11	1	ELECT	Electronic	70	
3	FT36W/2G11	1.5	ELECT	Electronic	105	Tandem wired
3	FT36W/2G11	2	ELECT	Electronic	107	
4	FT36W/2G11	2	ELECT	Electronic	140	(2) Two-lamp ballasts

LUMINAIRE LUMIN.

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Fluorescent Twin (40 W - F40TT Lamp)						
1	FT40W/2G11	1	MAG EE	Magnetic Energy Efficient	43	
2	FT40W/2G11	1	MAG EE	Magnetic Energy Efficient	86	
3	FT40W/2G11	1.5	MAG EE	Magnetic Energy Efficient	129	Tandem wired
3	FT40W/2G11	2	MAG EE	Magnetic Energy Efficient	130	
4	FT40W/2G11	2	MAG EE	Magnetic Energy Efficient	172	(2) Two-lamp ballasts
1	FT40W/2G11	1	ELECT	Electronic	36	
2	FT40W/2G11	1	ELECT	Electronic	71	
2	FT40W/2G11	1	ELECT	Electronic	70	
3	FT40W/2G11	1	ELECT	Electronic	98	
3	FT40W/2G11	1.5	ELECT	Electronic	106	Tandem wired
3	FT40W/2G11	2	ELECT	Electronic	107	
4	FT40W/2G11	2	ELECT	Electronic	142	(2) Two-lamp ballasts
2	FT40W/2G11	1	ELECT RO	Elec. Reduce Output (75%)	59	
3	FT40W/2G11	1.5	ELECT DIM	Electronic Dimming (to 1%)	105	Tandem wired
4	FT40W/2G11	2	ELECT DIM	Electronic Dimming (to 1%)	140	(2) two-lamp ballasts
Fluorescent Twin (50 W - F50TT Lamp)						
1	FT50W/2G11	1	ELECT	Electronic	54	
2	FT50W/2G11	1	ELECT	Electronic	106	
3	FT50W/2G11	1	ELECT	Electronic	98	
3	FT50W/2G11	1.5	ELECT	Electronic	159	Tandem wired
3	FT50W/2G11	2	ELECT	Electronic	160	
4	FT50W/2G11	2	ELECT	Electronic	212	(2) Two-lamp ballasts
Fluorescent Twin (55 W - F55TT Lamp)						
1	FT55W/2G11	1	ELECT	Electronic	62	
2 ft. Fluorescent U-Tube Octic (32W - FBO31T8 Lamp)						
1	FB31T8	0.5	MAG EE	Magnetic Energy Efficient	35	Tandem wired
1	FB31T8	1	MAG EE	Magnetic Energy Efficient	36	
2	FB31T8	1	MAG EE	Magnetic Energy Efficient	69	
3	FB31T8	1.5	MAG EE	Magnetic Energy Efficient	104	Tandem wired
3	FB31T8	2	MAG EE	Magnetic Energy Efficient	105	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
1	FB31T8	0.5	ELECT	Electronic	31	Tandem wired
1	FB31T8	1	ELECT	Electronic	39	
2	FB31T8	1	ELECT	Electronic	62	
3	FB31T8	1	ELECT	Electronic	92	
3	FB31T8	1.5	ELECT	Electronic	93	Tandem wired
3	FB31T8	2	ELECT	Electronic	101	
2	FB31T8	1	ELECT IS	Electronic Instant Start	61	
3	FB31T8	1	ELECT IS	Electronic Instant Start	88	
2 ft. Fluorescent U-Tube Energy-Saving (34W)						
1	FB40T12/ES	0.5	MAG EE	Magnetic Energy Efficient	36	Tandem wired
1	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	43	
2	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	72	
3	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	105	
3	FB40T12/ES	1.5	MAG EE	Magnetic Energy Efficient	108	Tandem wired
3	FB40T12/ES	2	MAG EE	Magnetic Energy Efficient	115	
1	FB40T12/ES	0.5	ELECT	Electronic	30	Tandem wired
1	FB40T12/ES	1	ELECT	Electronic	31	
2	FB40T12/ES	1	ELECT	Electronic	59	
3	FB40T12/ES	1	ELECT	Electronic	90	
3	FB40T12/ES	1.5	ELECT	Electronic	88	Tandem wired
3	FB40T12/ES	2	ELECT	Electronic	90	
2 ft. Fluorescent U-Tube Standard (40W - FB40T12 Lamp)						
1	FB40T12	0.5	MAG EE	Magnetic Energy Efficient	43	Tandem wired
1	FB40T12	1	MAG EE	Magnetic Energy Efficient	48	
2	FB40T12	1	MAG EE	Magnetic Energy Efficient	86	
3	FB40T12	1	MAG EE	Magnetic Energy Efficient	127	
3	FB40T12	1.5	MAG EE	Magnetic Energy Efficient	129	Tandem wired
3	FB40T12	2	MAG EE	Magnetic Energy Efficient	134	
1	FB40T12	0.5	ELECT	Electronic	35	Tandem wired
1	FB40T12	1	ELECT	Electronic	36	
2	FB40T12	1	ELECT	Electronic	67	
3	FB40T12	1	ELECT	Electronic	100	
3	FB40T12	1.5	ELECT	Electronic	101	Tandem wired
3	FB40T12	2	ELECT	Electronic	103	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Fluorescent Preheat T5 (4W)						
1	F4T5	1	MAG STD	Magnetic Standard	8	6" MOL
Fluorescent Preheat T5 (6W)						
1	F6T5	1	MAG STD	Magnetic Standard	10	9" MOL
Fluorescent Preheat T5 (8W)						
1	F8T5	1	MAG STD	Magnetic Standard	12	12" MOL
Fluorescent Preheat T8 (15W)						
1	F15T8	1	MAG STD	Magnetic Standard	19	18" MOL
Fluorescent Preheat T12 (15W)						
1	F15T12	1	MAG STD	Magnetic Standard	19	18" MOL
Fluorescent Preheat T12 (20W)						
1	F20T12	1	MAG STD	Magnetic Standard	25	24" MOL
2	F20T12	1	MAG STD	Magnetic Standard	50	24" MOL
Fluorescent Preheat T8 (30W)						
1	F30T8	1	MAG STD	Magnetic Standard	46	30" MOL
2	F30T8	1	MAG STD	Magnetic Standard	79	30" MOL
Fluorescent Preheat T12 (30W)						
1	F30T12	1	MAG STD	Magnetic Standard	46	30" MOL
2	F30T12	1	MAG STD	Magnetic Standard	79	30" MOL
2	F30T12	1	MAG EE	Magnetic Energy Efficient	74	30" MOL
1	F30T12	1	ELECT	Electronic	31	30" MOL
2	F30T12	2	ELECT	Electronic	63	30" MOL
2 foot Fluorescent Rapid Start T8 (17W)						
1	F17T8	1	MAG EE	Magnetic Energy Efficient	24	
2	F17T8	1	MAG EE	Magnetic Energy Efficient	45	
1	F17T8	1	ELECT	Electronic	22	
2	F17T8	1	ELECT	Electronic	33	
3	F17T8	1	ELECT	Electronic	53	
3	F17T8	2	ELECT	Electronic	55	
4	F17T8	1	ELECT	Electronic	63	
4	F17T8	2	ELECT	Electronic	66	(2) two-lamp ballasts

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
3 foot Fluorescent Rapid Start T8 (25W)						
1	F25T8	1	MAG EE	Magnetic Energy Efficient	33	
2	F25T8	1	MAG EE	Magnetic Energy Efficient	65	
1	F25T8	1	ELECT	Electronic	27	
2	F25T8	1	ELECT	Electronic	48	
3	F25T8	1	ELECT	Electronic	68	
3	F25T8	2	ELECT	Electronic	75	
4	F25T8	1	ELECT	Electronic	89	
4	F25T8	2	ELECT	Electronic	96	(2) two-lamp ballasts
4 foot Fluorescent Rapid Start Octic (32W)						
1	F32T8	0.5	MAG EE	Magnetic Energy Efficient	35	Tandem wired
1	F32T8	1	MAG EE	Magnetic Energy Efficient	39	
2	F32T8	1	MAG EE	Magnetic Energy Efficient	70	
3	F32T8	1.5	MAG EE	Magnetic Energy Efficient	105	Tandem wired
3	F32T8	2	MAG EE	Magnetic Energy Efficient	109	
4	F32T8	2	MAG EE	Magnetic Energy Efficient	140	(2) two-lamp ballasts
1	F32T8	0.5	ELECT	Electronic	31	Tandem wired
1	F32T8	1	ELECT	Electronic	32	
2	F32T8	1	ELECT	Electronic	62	
3	F32T8	1	ELECT	Electronic	93	
3	F32T8	1.5	ELECT	Electronic	93	Tandem wired
3	F32T8	2	ELECT	Electronic	94	
4	F32T8	1	ELECT	Electronic	114	
4	F32T8	2	ELECT	Electronic	124	(2) two-lamp ballasts
2	F32T8	1	ELECT IS	Electronic Instant Start	63	
3	F32T8	1	ELECT IS	Electronic Instant Start	96	
3	F32T8	1.5	ELECT IS	Electronic Instant Start	95	Tandem wired
4	F32T8	1	ELECT IS	Electronic Instant Start	124	
4	F32T8	2	ELECT IS	Electronic Instant Start	126	(2) two-lamp ballasts

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
4 foot Fluorescent Rapid Start Octic (32W) (cont.)						
2	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	51	
3	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	76	
3	F32T8	1.5	ELECT RO	Electronic Reduce Output (75%)	77	Tandem wired
4	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	100	
4	F32T8	2	ELECT RO	Electronic Reduce Output (75%)	102	(2) two-lamp ballasts
2	F32T8	1	ELECT TL	Electronic Two Level (50 & 100%)	65	
3	F32T8	1.5	ELECT TL	Electronic Two Level (50 & 100%)	98	Tandem wired
4	F32T8	2	ELECT TL	Electronic Two Level (50 & 100%)	130	(2) two-lamp ballasts
2	F32T8	1	ELECT AO	Electronic Adjustable Output (to 15%)	73	
3	F32T8	1.5	ELECT AO	Electronic Adjustable Output (to 15%)	110	Tandem wired
4	F32T8	2	ELECT AO	Electronic Adjustable Output (to 15%)	146	(2) two-lamp ballasts
2	F32T8	1	ELECT DIM	Electronic Dimming (to 1%)	75	
3	F32T8	1.5	ELECT DIM	Electronic Dimming (to 1%)	113	Tandem wired
4	F32T8	2	ELECT DIM	Electronic Dimming (to 1%)	150	(2) two-lamp ballasts
5 foot Fluorescent Rapid Start (40W)						
1	F40T8	1	MAG EE	Magnetic Energy Efficient	50	
2	F40T8	1	MAG EE	Magnetic Energy Efficient	92	
1	F40T8	1	ELECT	Electronic	46	
2	F40T8	1	ELECT	Electronic	79	
3	F40T8	2	ELECT	Electronic	109	
3 foot Fluorescent Rapid Start Energy-Saving (25W)						
1	F30T12/ES	1	MAG STD	Magnetic Standard	42	
2	F30T12/ES	1	MAG STD	Magnetic Standard	74	
3	F30T12/ES	1.5	MAG STD	Magnetic Standard	111	Tandem wired
3	F30T12/ES	2	MAG STD	Magnetic Standard	116	
2	F30T12/ES	1	MAG EE	Magnetic Energy Efficient	66	
1	F30T12/ES	1	ELECT	Electronic	26	
2	F30T12/ES	1	ELECT	Electronic	53	

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Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
3 foot Fluorescent Rapid Start Standard (30W)						
1	F30T12	1	MAG STD	Magnetic Standard	46	
2	F30T12	1	MAG STD	Magnetic Standard	79	
3	F30T12	1.5	MAG STD	Magnetic Standard	118	Tandem wired
3	F30T12	2	MAG STD	Magnetic Standard	125	
4 foot Fluorescent Rapid Start Energy-Saving Plus (32W)						
1	F40T12/ES Plus	0.5	MAG EE	Magnetic Energy Efficient	34	Tandem wired
1	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	41	
2	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	68	
3	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	99	
3	F40T12/ES Plus	1.5	MAG EE	Magnetic Energy Efficient	102	Tandem wired
3	F40T12/ES Plus	2	MAG EE	Magnetic Energy Efficient	109	
4	F40T12/ES Plus	2	MAG EE	Magnetic Energy Efficient	136	(2) Two-lamp ballasts
4 foot Fluorescent Rapid Start Energy-Saving (34W)						
1	F40T12/ES	0.5	MAG STD**	Magnetic Standard	42	Tandem wired
1	F40T12/ES	1	MAG STD**	Magnetic Standard	48	
2	F40T12/ES	1	MAG STD**	Magnetic Standard	82	
3	F40T12/ES	1.5	MAG STD**	Magnetic Standard	122	Tandem wired
3	F40T12/ES	2	MAG STD**	Magnetic Standard	130	
4	F40T12/ES	2	MAG STD**	Magnetic Standard	164	(2) Two-lamp ballasts
1	F40T12/ES	0.5	MAG EE	Magnetic Energy Efficient	36	Tandem wired
1	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	43	
2	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	72	
3	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	105	
3	F40T12/ES	1.5	MAG EE	Magnetic Energy Efficient	108	Tandem wired
3	F40T12/ES	2	MAG EE	Magnetic Energy Efficient	112	
4	F40T12/ES	2	MAG EE	Magnetic Energy Efficient	144	(2) Two-lamp ballasts
2	F40T12/ES	1	MAG HC	Magnetic Heater Cutout	58	
3	F40T12/ES	1.5	MAG HC	Magnetic Heater Cutout	87	Tandem wired
4	F40T12/ES	2	MAG HC	Magnetic Heater Cutout	116	(2) Two-lamp ballasts
2	F40T12/ES	1	MAG HC FO	Mag. Heater Cutout Full Light	66	
3	F40T12/ES	1.5	MAG HC FO	Mag. Heater Cutout Full Light	99	Tandem wired
4	F40T12/ES	2	MAG HC FO	Mag. Heater Cutout Full Light	132	(2) Two-lamp ballasts

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
4 foot Fluorescent Rapid Start Energy-Saving (34W) (cont.)						
1	F40T12/ES	0.5	ELECT	Electronic	30	Tandem wired
1	F40T12/ES	1	ELECT	Electronic	31	
2	F40T12/ES	1	ELECT	Electronic	62	
3	F40T12/ES	1	ELECT	Electronic	90	
3	F40T12/ES	1.5	ELECT	Electronic	93	Tandem wired
3	F40T12/ES	2	ELECT	Electronic	93	
4	F40T12/ES	1	ELECT	Electronic	121	
4	F40T12/ES	2	ELECT	Electronic	124	(2) Two-lamp ballasts
2	F40T12/ES	1	ELECT AO	Elec. Adjustable Output (to 15%)	60	
3	F40T12/ES	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	90	Tandem wired
4	F40T12/ES	2	ELECT AO	Elec. Adjustable Output (to 15%)	120	(2) Two-lamp ballasts
4 foot Fluorescent Rapid Start Standard (40W)						
1	F40T12	0.5	MAG STD**	Magnetic Standard	26	Tandem wired
1	F40T12	1	MAG STD**	Magnetic Standard	52	
2	F40T12	1	MAG STD**	Magnetic Standard	96	
3	F40T12	1.5	MAG STD**	Magnetic Standard	144	Tandem wired
3	F40T12	2	MAG STD**	Magnetic Standard	148	
4	F40T12	2	MAG STD**	Magnetic Standard	192	(2) Two-lamp ballasts
1	F40T12	0.5	MAG EE	Magnetic Energy Efficient	44	Tandem wired
1	F40T12	1	MAG EE	Magnetic Energy Efficient	46	
2	F40T12	1	MAG EE	Magnetic Energy Efficient	88	
3	F40T12	1	MAG EE	Magnetic Energy Efficient	127	
3	F40T12	1.5	MAG EE	Magnetic Energy Efficient	132	Tandem wired
3	F40T12	2	MAG EE	Magnetic Energy Efficient	134	
4	F40T12	2	MAG EE	Magnetic Energy Efficient	176	(2) Two-lamp ballasts
2	F40T12	1	MAG HC	Magnetic Heater Cutout	71	
3	F40T12	1.5	MAG HC	Magnetic Heater Cutout	107	Tandem wired
4	F40T12	2	MAG HC	Magnetic Heater Cutout	142	(2) Two-lamp ballasts

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Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
4 foot Fluorescent Rapid Start Standard (40W) (cont.)						
2	F40T12	1	MAG HC FO	Magnetic Heater Cutout Full Light	80	
3	F40T12	1.5	MAG HC FO	Magnetic Heater Cutout Full Light	120	Tandem wired
4	F40T12	2	MAG HC FO	Magnetic Heater Cutout Full Light	160	(2) Two-lamp ballasts
1	F40T12	0.5	ELECT	Electronic	36	Tandem wired
1	F40T12	1	ELECT	Electronic	37	
2	F40T12	1	ELECT	Electronic	72	
3	F40T12	1	ELECT	Electronic	107	
3	F40T12	1.5	ELECT	Electronic	108	Tandem wired
3	F40T12	2	ELECT	Electronic	109	
4	F40T12	1	ELECT	Electronic	135	
4	F40T12	2	ELECT	Electronic	144	(2) Two-lamp ballasts
2	F40T12	1	ELECT RO	Electronic Reduce Output (75%)	61	
3	F40T12	1	ELECT RO	Electronic Reduce Output (75%)	90	
3	F40T12	1.5	ELECT RO	Electronic Reduce Output (75%)	92	Tandem wired
4	F40T12	2	ELECT RO	Electronic Reduce Output (75%)	122	(2) Two-lamp ballasts
2	F40T12	1	ELECT TL	Elec. Two Level (50 & 100%)	69	
3	F40T12	1.5	ELECT TL	Elec. Two Level (50 & 100%)	104	Tandem wired
4	F40T12	2	ELECT TL	Elec. Two Level (50 & 100%)	138	(2) Two-lamp ballasts
2	F40T12	1	ELECT AO	Elec. Adjustable Output (to 15%)	73	
3	F40T12	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	110	Tandem wired
4	F40T12	2	ELECT AO	Elec. Adjustable Output (to 15%)	146	(2) Two-lamp ballasts
2	F40T12	1	ELECT DIM	Electronic Dimming (to 1%)	83	
3	F40T12	1.5	ELECT DIM	Electronic Dimming (to 1%)	125	Tandem wired
4	F40T12	2	ELECT DIM	Electronic Dimming (to 1%)	166	(2) Two-lamp ballasts

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Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
4 foot Fluorescent Rapid Start Extended Output (42W)						
2	F40T10/EO	1	MAG EE	Magnetic Energy Efficient	92	
3	F40T10/EO	1.5	MAG EE	Magnetic Energy Efficient	138	Tandem wired
4	F40T10/EO	2	MAG EE	Magnetic Energy Efficient	184	(2) Two-lamp ballasts
2	F40T10/EO	1	MAG HC	Magnetic Heater Cutout	74	
3	F40T10/EO	1.5	MAG HC	Magnetic Heater Cutout	111	Tandem wired
4	F40T10/EO	2	MAG HC	Magnetic Heater Cutout	148	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT	Electronic	74	
3	F40T10/EO	1.5	ELECT	Electronic	111	Tandem wired
4	F40T10/EO	2	ELECT	Electronic	148	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT RO	Electronic Reduce Output (75%)	63	
3	F40T10/EO	1.5	ELECT RO	Electronic Reduce Output (75%)	95	Tandem wired
4	F40T10/EO	2	ELECT RO	Electronic Reduce Output (75%)	126	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT TL	Elec. Two Level (50 & 100%)	72	
3	F40T10/EO	1.5	ELECT TL	Elec. Two Level (50 & 100%)	108	Tandem wired
4	F40T10/EO	2	ELECT TL	Elec. Two Level (50 & 100%)	144	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT AO	Elec. Adjustable Output (to 15%)	73	
3	F40T10/EO	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	110	Tandem wired
4	F40T10/EO	2	ELECT AO	Elec. Adjustable Output (to 15%)	146	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT DIM	Electronic Dimming (to 1%)	85	
3	F40T10/EO	1.5	ELECT DIM	Electronic Dimming (to 1%)	128	Tandem wired
4	F40T10/EO	2	ELECT DIM	Electronic Dimming (to 1%)	170	(2) Two-lamp ballasts

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Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
8 foot Fluorescent Rapid Start High Output Energy-Saving (86W)						
2	F96T8/HO	1	ELECT	Electronic	160	
8 foot Fluorescent Rapid Start High Output Energy-Saving (95W)						
1	F96T12/HO/ES	1	MAG STD	Magnetic Standard	125	
2	F96T12/HO/ES	1	MAG STD**	Magnetic Standard	227	
2	F96T12/HO/ES	1	MAG EE	Magnetic Energy Efficient	208	
4	F96T12/HO/ES	2	MAG EE	Magnetic Energy Efficient	416	(2) Two-lamp ballasts
2	F96T12/HO/ES	1	ELECT	Electronic	160	
4	F96T12/HO/ES	2	ELECT	Electronic	320	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start High Output (110W)						
1	F96T12/HO	1	MAG STD	Magnetic Standard	140	
2	F96T12/HO	1	MAG STD**	Magnetic Standard	252	
2	F96T12/HO	1	MAG EE	Magnetic Energy Efficient	237	
4	F96T12/HO	2	MAG EE	Magnetic Energy Efficient	474	(2) Two-lamp ballasts
2	F96T12/HO	1	ELECT	Electronic	190	
4	F96T12/HO	2	ELECT	Electronic	380	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start Very High Output Energy-Saving (195W)						
1	F96T12/VHO/ES	1	MAG STD	Magnetic Standard	200	
2	F96T12/VHO/ES	1	MAG STD	Magnetic Standard	325	
4	F96T12/VHO/ES	2	MAG STD	Magnetic Standard	650	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start Very High Output (215W)						
1	F96T12/VHO	1	MAG STD	Magnetic Standard	230	
2	F96T12/VHO	1	MAG STD	Magnetic Standard	440	
4	F96T12/VHO	2	MAG STD	Magnetic Standard	880	

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Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
4 foot Fluorescent Slimline Energy-Saving T12 (32W)						
1	F48T12/ES	1	MAG STD	Magnetic Standard	51	
2	F48T12/ES	1	MAG STD	Magnetic Standard	82	
4 foot Fluorescent Slimline Standard T12 (39W)						
1	F48T12	1	MAG STD	Magnetic Standard	59	
2	F48T12	1	MAG STD	Magnetic Standard	98	
8 foot Fluorescent Instant Start T8 (Slimline with Rare Earth Phosphors)						
1	F96T8	1	ELECT	Electronic	71	
2	F96T8	1	ELECT	Electronic	115	
8 foot Fluorescent Slimline Energy-Saving (60W)						
1	F96T12/ES	1	MAG STD	Magnetic Standard	83	
2	F96T12/ES	1	MAG STD**	Magnetic Standard	138	
2	F96T12/ES	1	MAG EE	Magnetic Energy Efficient	123	
4	F96T12/ES	2	MAG EE	Magnetic Energy Efficient	246	(2) Two-lamp ballasts
2	F96T12/ES	1	ELECT	Electronic	105	
4	F96T12/ES	2	ELECT	Electronic	210	(2) Two-lamp ballasts
8 foot Fluorescent Slimline Standard (75W)						
1	F96T12	1	MAG STD	Magnetic Standard	100	
2	F96T12	1	MAG STD**	Magnetic Standard	173	
2	F96T12	1	MAG EE	Magnetic Energy Efficient	158	
4	F96T12	2	MAG EE	Magnetic Energy Efficient	316	(2) Two-lamp ballasts
2	F96T12	1	ELECT	Electronic	130	
4	F96T12	2	ELECT	Electronic	260	(2) Two-lamp ballasts
2	F96T12	1	ELECT IS	Electronic Instant Start	130	
3	F96T12	1.5	ELECT IS	Electronic Instant Start	195	Tandem wired
4	F96T12	2	ELECT IS	Electronic Instant Start	260	(2) Two-lamp ballasts

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Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Mercury Vapor						
1	MV40	1	MAG STD	Magnetic Standard	51	
1	MV50	1	MAG STD	Magnetic Standard	63	
1	MV75	1	MAG STD	Magnetic Standard	88	
1	MV100	1	MAG STD	Magnetic Standard	119	
1	MV175	1	MAG STD	Magnetic Standard	197	
1	MV250	1	MAG STD	Magnetic Standard	285	
1	MV400	1	MAG STD	Magnetic Standard	450	
1	MV1000	1	MAG STD	Magnetic Standard	1080	
Metal Halide						
1	MH32	1	MAG STD	Magnetic Standard	42	
1	MH70	1	MAG STD	Magnetic Standard	95	
1	MH100	1	MAG STD	Magnetic Standard	142	
1	MH175	1	MAG STD	Magnetic Standard	210	
1	MH250	1	MAG STD	Magnetic Standard	295	
1	MH400	1	MAG STD	Magnetic Standard	461	
1	MH1000	1	MAG STD	Magnetic Standard	1080	
High Pressure Sodium						
1	HPS35	1	MAG STD	Magnetic Standard	44	
1	HPS50	1	MAG STD	Magnetic Standard	61	
1	HPS70	1	MAG STD	Magnetic Standard	93	
1	HPS100	1	MAG STD	Magnetic Standard	116	
1	HPS150	1	MAG STD	Magnetic Standard	173	
1	HPS200	1	MAG STD	Magnetic Standard	240	
1	HPS250	1	MAG STD	Magnetic Standard	302	
1	HPS400	1	MAG STD	Magnetic Standard	469	
1	HPS1000	1	MAG STD	Magnetic Standard	1090	
Low Pressure Sodium						
1	LPS18	1	MAG STD	Magnetic Standard	30	
1	LPS35	1	MAG STD	Magnetic Standard	60	
1	LPS55	1	MAG STD	Magnetic Standard	80	
1	LPS90	1	MAG STD	Magnetic Standard	125	
1	LPS135	1	MAG STD	Magnetic Standard	178	
1	LPS180	1	MAG STD	Magnetic Standard	220	

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Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
12 Volt Tungsten Halogen, MR 16 & Electronic Transformer						
1	Q20MR16(12V)	1	ELECT	Electronic	23	
1	Q35MR16(12V)	1	ELECT	Electronic	39	
1	Q50MR16(12V)	1	ELECT	Electronic	55	
1	Q70MR16(12V)	1	ELECT	Electronic	78	

*** US Energy Policy Act of 1992 affect on lamps**

Beginning in April 1994, many common wattage lamp types can no longer be manufactured or imported into the U.S. Federal Energy Legislation has decreed that these lamp types must be eliminated to reduce energy consumption.

Fluorescent Lamps	F40U/3 Cool White	F96T12/ W
F40 CW	F40U/3 Warm White	F96T12/ WW
F40 D	F40U/6 Cool White	F96T12/ WWX
F40 D/WM	F40U/6 Warm White Deluxe	F96T12/ WWX/WM
F40 W	F40U/6 Warm White	F96T12/ HO/D
F40 WW	F96T1 CW	F96T12/ HO/CW
	2/	
F40 WWX	F96T1 D	F96T12/ HO/W
	2/	
F40 WWX/WM	F96T1 D/WM	F96T12/ HO/WW
	2/	

Incandescent PAR Lamps		Inc. Reflector Lamps
75PAR38	150PAR38	75R40 200R40
75/65PAR38	150/120PAR38	75R30
100/80PAR38		150R40
100 PAR38		100R40

**** US National Appliance Energy Conservation Act of 1988 affect on ballasts**

In 1991 using the following Standard Magnetic ballasts was not permitted in the US.

- Single and two-lamp ballasts for 4' T12 Rapid Start Lamps, 120V & 277V 60Hz
- Two-lamp ballasts for 8' T-12 Slimline lamps
- Two-lamp ballasts for 8' T12 high-output rapid start lamps